W. J. Gibbins

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Bolton

GUIDE

FOR USING

MEDICAL BATTERIES:

(BEING A COMPENDIUM FROM HIS LARGER WORK ON MEDICAL ELECTRICITY AND NERVOUS DISEASES,)

SHOWING

THE MOST APPROVED APPARATUS, METHODS AND RULES,

FOR

The Medical Employment of Electricity

IN THE TREATMENT OF

NERVOUS DISEASES.

BY

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TO

JOHN HOMANS, M. D.,

PRESIDENT OF THE MASSACHUSETTS MEDICAL SOCIETY, MEMBER OF THE AMERICAN MEDICAL ASSOCIATION, MEMBER OF THE SOCIETY OF MEDICAL IMPROVEMENT, ETC.,

TO WHOM, DURING MANY YEARS OF PROFESSIONAL LIFE, IT HAS BEEN MY HAPPINESS TO LOOK AS A REVERED FELLOW OF OUR NOBLE ART,

MY COUNSELLOR AND FRIEND,

WITH FEELINGS OF ADMIRATION FOR HIS LIBERAL PRINCIPLES, PROFESSIONAL INTEGRITY AND FORECAST, AND WITH NO LESS GRATITUDE FOR HIS EXERTIONS IN THE GENERAL CAUSE OF

Medical Science,

THIS HUMBLE THOUGH ARDUOUS WORK

IS GRATEFULLY DEDICATED.

PREFACE.

THIS little volume is intended to be a concise *practical guide* to the medical and surgical uses of electrical apparatus—it being a *synopsis*, or rather a condensation, of a portion of my larger work—"*Medical Electricity* and *Nervous Diseases*." The recent improvements in philosophical appliances, the increased knowledge and skill in electro-physiology and pathology, and the important relation which electricity is now known to bear to most nervous affections, as also to many complicated chronic and obscure diseases, call imperatively for the best of apparatus, a more general knowledge of their offices and powers, and a study of the most simple and effective methods and rules for their use and safety.

Electricity, derived either as galvanism or as electro-magnetism, is already recognized, by a large portion of the best educated of the medical profession, as a peculiar natural remedy. It cannot be ignored. Henceforth the prudent practitioner will not be found without this magic remedial aid. Hence a widespread knowledge of medical batteries, and their uses, is demanded, both as a caution for the public against quacks and empirics, and for the credit and greater usefulness of the medical profession.

In printing this book, the complete electrotype plates of the larger work from which it is taken are used; hence the appearance of some figures, referring to cuts and pages not herein to be found.

GUIDE

TO THE USE OF MEDICAL BATTERIES.

CHAPTER I.

ELECTRICAL INSTRUMENTS FOR MEDICAL PURPOSES.

Very often the question still arises in effect, Is Medical Electricity an art as well as a science? Is it a tangible remedy, that in certain cases and conditions can work a lasting, permanent cure? If simply holding two *handle*-electrodes of an active battery respectively in the two hands of the patient,— or while one is thus held, the other is somewhere applied over the head, body, or limbs — or the patient is to be shocked, no matter how, — evidently but very little skill is demanded in the applications of electricity, and scarcely could it be termed an art.

Medical electricity *is both* — a science and an art. A good medical battery, with its various electrodes, may be compared to a surgeon's case of instruments. It is not the instrument, in itself, that gives relief, or brings about the safety and cure of the patient, but it is the skill of the operator in using the instrument. Equally true is it here. In this light only must we employ electricity as a remedy.

The *mode* in which it is applied to the human body or limbs, therefore, has an all-important bearing upon the result. Indeed, it is only by this intelligible discrimination in selecting

the *cases*, the *stage* of the affection, the *form* of the electricity, and *the method of its application*, that any marked and uniform success can possibly be expected.

It is true, that by only a random employment of electricity a few accidental and truly wonderful successes have been obtained; but with a multitude of failures, and not a few truly injurious effects. On the other hand, we do know, by observing certain rules and methods, that the nerves and organs, under certain circumstances, can be called into natural action more certainly and more thoroughly by means of electricity than by any other known agency or remedy. In fact, we are able, by merely varying the form of electricity, or the mode of application, to arouse or to allay their vital power; to diminish or increase their true functional action. Thus, while we would not claim for electricity a *cure-all*, we do insist that it is one of our most valuable aids in certain diagnoses, and one of our most controllable and precious remedies.

For therapeutical means we may have recourse to three *classes* of electrical instruments, viz., the Electric Machine, the Galvanic Battery, or the Induction Apparatus. There is quite a variety of instruments in all three classes; but we should choose them according to their *action* and the *form* of the element they respectively produce. Electricity in motion, be it remembered, results from the reunion or neutralization of the two separated opposite electric principles. This may be *instantaneous*, *intermitted*, or *continuous*. In the former case it constitutes the simple *discharge;* in the second case a more or less *continuous* current; in the third there are produced rapidly *interrupted* currents, which are usually as frequently alternated or reversed.

By the *electrical machine* we get a peculiar form of electricity for remedial purposes, possessing *great intensity*, while there is but *feeble quantity*. This machine may consist of a revolving cylinder, or plate of glass, which is submitted to the friction of cushions or rubbers. As a general thing, a plate machine is, for equal size, of far higher power than the cylinder; but it matters very little which form of friction machine is used. If we were going to purchase for practical purposes, we should de-

cidedly prefer the plate machine, and the plate should not measure less than twenty inches. The room for operating should be a dry one. When the air is moist it must be dried and warmed by furnace heat, or other means, and the glass plate, as well as the insulating supporters of the prime conductor, of the axle of the glass and of the rubber, should be rubbed with a hot, dry cloth, not only to free the machine of moisture, but also from dust, which is as hurtful as moisture to the preservation of electricity on insulated conductors. Hence, the apparatus, together with all the appliances about it, must be kept scrupulously neat and dry.

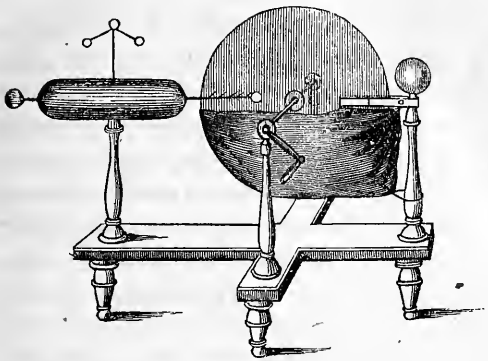


Fig. 36.

I have found that in humid weather, or when the atmosphere is negative as from an approaching storm, that if the glass plate is moistened with a very trifle of sweet oil, it is of advantage; also, that the surface of the rubbers must be from time to time renewed with an amalgam powder of zinc, or deuto-sulphuret of tin, which can be had of any philosophical instrument maker. Another arrangement or provision is also necessary; and that is, a good contact conductor with the actual moist earth, or a large body of metal. This should be some way adjustable near the machine, so as to be readily put in contact with the rubber, or negative pole, while we are charging the prime conductor *positively*, as also for drawing sparks from the patient, or for charging the Leyden jars; also, so that at another time it can be removed to the prime conductor while we are employing *negative* electricity from the rubber end of the machine, for the rubber is always the negative, and the prime conductor is positive. And here comes in the *law, that the one is never evolved without the other;* therefore, if we wish to use or accumulate the one, the

other must be as freely dissipated without hinderance, and if this point is well attended to, the power and uniformity of the machine will be greatly enhanced. The dry wall or chimney of the house is not always sufficient. A large copper wire leading to the moist earth, or connected with a water pipe, or gas pipe, by good metallic contact, is the most reliable. But, of course, where we wish to employ both electricities at once, we must not make either the rubber or the prime conductor communicate with the ground, but rather keep all well insulated. In every case the electricity is set free on the *surface* of the rubbed glass plate, or cylinder, the negative flying to the rubber, while the positive accumulates upon the glass, which induces it also by sharp points in the prime conductor; and from here we can accumulate even greater quantities still by means of Leyden jars. The power of the jar is in proportion to the size; i. e., a half gallon jar is twice as powerful as a quart jar, if each is fully charged; for the former will receive twice as many turns of the machine to charge it. If the outside tin foil coverings of two or more of these jars are put in communication, as, for instance, if set upon a sheet of tin foil, and at the same time the metal stems that communicate with the inner lining foil are joined also as by a chain, they thus become by this double connection as one jar, and can be charged and discharged through any one alone. This is called a *battery of friction electricity.*

Fig. 37.

Thus the inner coat of the jar receives positive electricity from the prime conductor, while negative electricity is then always accumulated on the outside of the jar, or conductor that leads it off. Now, if a communication is made between the inner and the outer coatings of the jar directly, as by means of a discharge, or indirectly, as through the human body, a neutralization of the two electricities takes place with a loud crack and flash. If the negative charge is required, the prime conductor must communicate with the *outer* covering of the jar, &c.; but usually it is the positive charge that we have to do with. If the jar is discharged through the human body, there is a violent,

sudden, and unpleasant sensation, which we term the *electric shock*. The strength of this shock is mainly in direct ratio to the extent of the metallic coating of the jar, and to the degree of high intensity with which that is charged and the susceptibility of the patient who receives it. This may be transmitted through one person, or even through a great number of persons in a chain, if the first person takes hold of the recently charged jar near its bottom, while the last person in the circle then touches with his finger the knob or ball on the top of the jar, and while they all hold each other by the hand. If several jars are properly united and fully charged, they might give a shock through the human body, by its action on the nervous system and the natural animal-currents that would exhaust them to such a degree, that it might prove as fatal as lightning itself.

The *discharger* is a necessary accompaniment of this machine, which consists either of stationary or adjustable metal arms, tipped with brass balls, and provided with a long glass handle. I find that *two* of these dischargers are more convenient than one, as for making discharges through the pelvis from the sacrum or lumbar region to the top of the pubis, in cases of dismenorrhœa. But it is necessary to approach the charged Leyden jar with the brass balls of the discharger *always in one order;* and that is, *first* make a ball to come in contact with the *outside of the charged jar*, *before* the contact is made with the knob on the top of the jar; for if the machine works well, and the reverse order is carelessly taken, i. e., to touch the top knob first, and then the outside of the jar the last, it will be very likely to break or to be perforated, and thus spoil the jar for further use. Another condition already alluded to, is necessary to succeed the best possible in charging a Leyden jar — for in medical practice but one or two at most are ever wanted. The outer foil of the jar must be in communication with the conductor to the earth, so as to utterly dissipate the negative electricity from outside the jar while it is being charged inside positively. But I must here take space

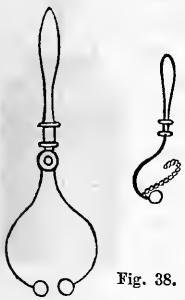


Fig. 38.

to remind you that it is believed that not an atom of positive electricity leaves the glass plate or cylinder that is rubbed, to pass to the prime conductor. The cylinder or plate is rendered positive by friction, and merely acts upon the electricity that is naturally in the prime conductor by induction, decomposing it into the two parts, and attracting the negative fluid, which accumulates in a state of high tension or elasticity, darts off towards the glass to combine with the positive fluid already commencing to be free on its surface, and so reconstituting the neutral or natural electricity. Thus the prime conductor is left powerfully positive, and so all things in contact with it, if also insulated, *not by acquiring electricity from the glass*, but rather by the *abstraction* of its own negative element, while simply *leaving* the positive electricity there.

When charging a Leyden jar, we can judge, after a little experience, how great is the charge from the number of turns of the machine, if we first ascertain that it is working well; but a more accurate means is Lane's discharging electrometer, or by Henley's quadrant electrometer.

To be prepared to use frictional electricity as a therapeutic, we need to be provided with the insulating Chair and Stool. The patient can be placed on the stool, but it is better to place him or her in the insulating chair with the feet upon the insulating stool; or if in bed, by placing the bedstead posts, or feet of the lounge, into thick glass salt cups. The patient thus situated can be *electrified positively* by connecting him with the prime conductor, or *negatively* by the rubber connection, by means of the long discharger, or by means of the chain, or by a large copper wire tipped with balls. By a steady and lively turning of the machine, the patient can be kept at this state for a half hour together, notwithstanding the continual insensible discharge that is constantly going on into the air. If in the dark, this phenomenon becomes visible, as the tips of the hairs and every other angle will appear luminous, or emit sparks even, if approached by a conductor to any part of the person.

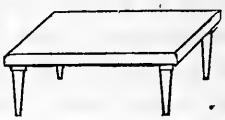


Fig. 39.

When a patient is insulated and gradually charged from the prime conductor *positively* to a high degree of tension, and thus continued for a little while, during this if any *pointed* director is placed near him, the plus electricity is by it drawn off at that vicinity very quietly, and almost insensibly, only giving rise to the phenomenon called *aura*. This acts as a *mild*, but most excellent local alterative stimulus; as, for instance, about the eyes and breast. But if we remove the *pointed* director, and in its place use a *ball*, then the electricity is drawn off from the patient in *sparks*, which produce a pricking sensation, much as if the skin were touched with a pin or needle; and the physiological result is also quite different. This succession of sparks produces much the same effect *locally* as the passage of a gentle voltaic current. The effect of these sparks (which can be made more seldom, long, and powerful, or rapid, short, and gentle, according as the brass ball is made to *approximate*, more or less, to the part) acts as a stimulus of a very peculiar kind; because, as Dr. Golding Bird says, besides the simple discharge, there probably is accumulated and *localized* in the flesh positive electricity, at and near the spot where the sparks leave the body, which is thus maintained in wavering density. The skin soon becomes red, which shows its effects on the capillary vessels and at the roots of the hairs. Drawing sparks from the back of a cat is easily done in dry, frosty weather, particularly if pussy is near the fire, simply by first smoothing her fur with a very warm and dry silk, then lightly stroking the fur in the wrong direction, when she will soon give you to understand that she does not like it. These sparks have an in-working at the moist roots of the hairs, and are of the very minutest quantity, but of the highest possible intensity.

It is well to know that in a room where the friction machine is being worked, every single object in that room is negatively electrified, if the rubber end of the machine is put in connection with the room by means of a trailing chain over the table and floor, instead of being in connection with the earth; and so can they become positively charged by reversing the order.

High-pressure steam can be so directed through crooked tubes

and friction on wood, as to produce a profusion of high tension electricity, that by far exceeds any friction electrical machine. We saw an apparatus both in London and in Paris made expressly for this purpose, called the *hydro-electric* machine. By this not only a patient, but a whole ward, patients and all, could be so situated and maintained by it for any requisite time. But according to my own experience, the utility of tension by insulation is quite limited to a few certain cases and conditions, which will be clearly designated when I come to treat of its therapeutic application for nervous diseases.

Galvanic Electricity and Apparatus.

This term is given to that important form of electricity that is produced by *chemical action*. But probably the most simple example of this kind of electricity is shown by merely enclosing the tongue, for instance, between two different clean metals, from which the current is instantly set in motion, even sufficient to be sensible. This may be proved by any one, if they place a piece of silver or gold on the one side of the tongue, and then at the same time a piece of copper or zinc on the other side of the tongue, or, what is better still, simply a piece of clean zinc on the one side, while there is a piece of clean silver on the other. As long as the metals are so placed and held, there is no taste or sensation; but if now the outer edges of the two metals are brought together, or if by means of a bit of wire they are brought in contact or communication, then instantly there is demonstrated the galvanic action. If this does not readily appear at the first contact, repeat the opening and closing of the metallic contact quick or slow, and it will be decidedly manifested both by taste and sensation.

When two metals are placed in contact direct, or by means of a connecting wire, and when these are placed in a liquid or liquids capable of acting upon the one more than upon the other, then that peculiar electricity is evolved that we term *voltaic electricity*, *galvanic electricity*, or *galvanism*. The original *pile* for producing this current was devised by Dr. Volta, an

Italian physician, owing to the interpretation which this celebrated philosopher gave to the marvellous experiment of his contemporary, Dr. Luigi Galvani, of Bologna, namely, that a frog undergoes a violent agitation, when one of its nerves, being exposed, is touched with one metal, and at the same time its muscles are touched with another metal, while the two metals themselves are in contact.

Volta, and most natural philosophers since him, have supposed that the liberation of the current was entirely due to the *contact* of the two different kinds of metals, whilst the liquid between them plays merely the part of a conductor. To prove this, he invented his pile; and hence the term voltaic electricity. But it has since been proved by the researches of Sir Humphry Davy, M. Becquerel, M. De la Rive, and Professor Faraday, that the real source of the electricity is not from simple contact, but from the chemical action of two heterogeneous bodies; that contact is a condition most frequently necessary, but not always absolutely indispensable to the manifestation of electricity; that voltaic, or otherwise called galvanic electricity, may be produced by any chemical action; not only by the action of some liquid upon a solid, but likewise by the action of two or more dissimilar liquids upon each other; or even by gases acting upon gases, liquids, or solids. All agreed then, as now, that the effect produced upon the frog was due to the action of electricity; and as Galvani was the first discoverer of the phenomenon, this electricity is termed Galvanic, and the physical science concerned in it is called *Galvanism*. But to the pile itself, says De la Rive, must remain the name of its illustrious inventor.

Voltaic Piles or Apparatus. — All *moist* batteries, and the so-called "*dry batteries*" of every description, are termed *voltaic*, and provide only a primary current of electricity. Wet batteries are called *galvanic;* and from these two sources we derive all *primary* currents of electricity, which we term *galvanism* (in contradistinction to *faradaism*).

The original *Voltaic pile*, as first formed by Volta, was in the shape of a vertical column, formed of disks of copper and zinc of some two inches in diameter, and arranged as follows: —

A copper disk is first placed upon a glass, or some other insulating plate; a zinc disk is then placed directly upon the copper disk; and then the next disk is of cloth, well moistened with water, salt water, or acidulated water, which is then placed upon the zinc disk. A second similar pair is piled upon the first, a third upon the second, and so on to some fifty or a hundred pairs; each pair in the same exact order, i. e., first a copper and then a zinc, and each pair separated from the next pair by the wet cloth, and the whole retained in a pile by three or four perpendicular glass rods.

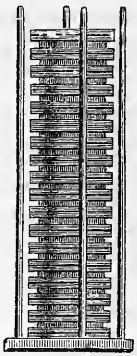


Fig. 40. Voltaic Pile.

This pile is found to be charged with negative electricity at its lower extremity, which is copper, and with positive electricity at its top, which is zinc. The top and bottom ends of this series or pile are called the *poles*. As soon as the poles of the pile are united by a conducting wire, the water that moistens the cloth between the several pairs becomes decomposed, and hydrogen is attracted to the copper, and the oxygen to the zinc. Then by this chemical action there is an electro-motive *force* set in action, which decomposes the natural or latent electricity of the metals into positive and negative electricity, the former accumulating upon the zinc pole in this arrangement, and the latter upon the copper. This pile may be laid down, or turned the other end up, — still is the zinc the positive pole, and the copper the negative. But here let me call particular attention to the *fact*, that this is exactly the *reverse* of what obtains in all our metallic pairs in liquid batteries, — for then the copper is the positive, while the zinc is the negative pole; but this can be easily explained. From this fact not being *heeded* a deal of confusion and misunderstanding has always resulted. The batteries with which we have to do, then, give the most oxidizable metal, which is zinc, as the negative pole; while the least oxidizable metal, which is copper, or silver, or platinum, is the positive pole; but in a moist or dry pile, the reverse is the result. Let these facts be retained.

The *Dry pile* is constructed much as Volta's original moist pile; but it is not an absolutely dry pile after all, for in that case it would not act. To prepare the permanent dry pile, large, stout sheets of brown paper are coated on the one side with tin foil, which answers to the place of the zinc in other batteries, and the other side of the paper is coated with the peroxide of manganese, which answers to copper. The paper is first tinned on one side only; on the other side the manganese is spread by means of a soft brush. The powder of peroxide of manganese is prepared in a fluid paste and milk. When the sheets are dry they are cut neatly in squares for disks. These are then laid in the same order, the one above the other, so that a face of tin and another of manganese may always be in contact in all the layers; while between every pair, or two such leaves, there may also be placed a blank sheet of the paper, and thus hundreds, or even thousands, may be built up to compose the dry pile. But the paper evidently gathers a minutia of moisture from the atmosphere, and this is the acting agent. This pile, being built upon an insulator, terminates at its top and bottom with the opposite kinds of metals; the tin is the negative pole, while the manganese is the positive pole. This pile cannot yield any very appreciable current, and yet it will for years give small sparks between its poles at any time. This shows its peculiar polarity, or tendency to *accumulate* tension electricity at its extremities or poles.

But to return. If the two poles of the voltaic pile be connected by a conducting wire, then the two opposite electricities travel towards each other over the same wire to neutralize where they started from, which is at the zinc or most oxidizable metal. But as there is a certain continuous supply, there will also be a continuous process or *current* as long and in proportion as the chemical action continues. Hence it results that *the power of this pile is variable;* it begins to diminish from the moment it is laid up, and in a short time it totally ceases,—the copper disks having been covered with hydrogen together with oxide of zinc, from the decomposition of sulphate zinc, while the zinc disks are also loaded with their own oxide. This was

a great inconvenience; besides, it gave the widest variety of results.

To avoid this trouble it was proposed to substitute for these disks a *trough* of liquid; and this necessarily converted the arrangement into a horizontal succession, instead of a perpendicular pile. The disks or plates were then to be rectangular, in the place of being circular; each two dissimilar metal pairs were to be in contact, and the whole series to be wedged tightly in the wooden trough, and so adjusted that they formed *cells*, and could be filled with the acidulated water in the trough at pleasure. This improvement was first pointed out by M. Cruikshank, and was then arranged for and given by the Emperor Napoleon to the great Polytechnic School of France. It was with this battery that MM. Gay-Lussac and Thénard, in 1808, made their splendid experiments; yet this cell trough was almost as troublesome as the original pile, but it possessed the advantage of more uniform and greater power *when cleaned* and put together anew for work.

Galvanic Batteries.

Galvanic or Voltaic Apparatus, from which alone we must obtain the *primary* current of electricity, suitable for medical and surgical purposes, should possess the following indispensable or desirable qualities, — all of which, however, I have never found in any one simple arrangement: —

First, there must be uniformity of action; i. e., the battery must continue to work at about the same given rate, at least during the office hours of a day; and if it runs thus reliably for weeks or months together, and keeps in order, all the better.

Second, there should be produced a very *large quantity* of electricity, *without intensity*, as when required for cauterization.

Third, there should be provided both large *quantity and intensity*, as when needed for electrolysis and catalysis; i. e., for chemical effects in the tissues; as through ill-nourished, atrophied, and degenerated muscles; for dropsical joints; for gouty and rheumatic callosities; and for changing the polarity of large nerve-trunks.

Fourth, a primary *intense* current is required; such, for instance, as can be temporarily produced by a new and full Pulvermacher chain, for reflex action, and for a certain class of neuralgias.

Fifth, for healing old ulcers; for restoring nervous and nutritive processes, as in many cold or lifeless limbs; for toning the sphincter ani and the cervix uteri; also, for allaying morbid irritability in those parts, by a reversed arrangement, a *small quantity*, with still less intensity, is all that is requisite.

Whether from one machine or many, the required current should be handy, reliable, and controllable. That is, the dose of primary electricity to be employed, when used directly as such, should be easily and accurately graduated and measured, without the necessity of depending upon the impressions of the patient, which must be variable in different cases, and hence entirely unreliable. At the same time, it is equally important to be attentive to the effects produced, and to learn of the patient also the kind of sensation or degree of impression or suffering, if any at all, that may result.

Engaged constantly in this special practice, the author has found it practicable to keep in ceaseless action and readiness, during many years, a variety of these sources of true primary galvanism. By means of the key-board we are also able to bid up any amount of intensity or quantity, or both these qualities of electricity, from one element to one hundred and thirty, arranged in three different series and sizes, for meeting a wide range of indications. But the most of such apparatus is ponderous, and suitable only for office or hospital use. The general practitioner, requiring portableness, must be content with such compact, durable, and clean arrangement as he can best command, to meet the greatest needed indications. For this end I arranged the "*Petit*" *battery*, as manufactured by T. Hall, 15 Bromfield Street, Boston. It is not a primary battery, but it yields only a *one-way* current, the *extra current* of chemical action; and is very portable, powerful, and penetrating. But some physicians prefer the portable *constant battery* of T. Hall, Boston; or the improved vibrator and helix *Smee battery* of

J. Kidder, New York. Some of these, or other good faradaic to-and-fro apparatus, must generally make up his electro-medical armamentarium.

Cruikshank's battery was then improved in various ways, until the cells of the trough were made to receive two plates of dissimilar metals, as before, it is true, but not of the same pair; i. e., one plate of a pair was in one cell, while the other plate was in the next cell, yet so as to be lifted out or put in, so that every cell received a pair of copper and zinc in the same liquid, not in metallic contact between themselves, as in the original, but connecting only with its next neighbor. This is the true arrangement of a galvanic battery as first shown by Becquerel. The author saw the remains of such a battery, which was provided for Sir H. Davy, in the laboratory of the Museum building of the Royal College of Physicians and Surgeons in London. Although only some eight or ten cells were in each trough, yet such a number of these were provided in connection, as to give him a battery of some two thousand pairs. It was with such ample means that Davy, and, still more recently, Faraday, made their splendid discoveries.

Dr. Wollaston found that the effect of this battery was still further augmented in power, for the same number of cells, if there was a greater surface given to the copper than to the zinc. This double-sized copper characterized the Wollaston battery.

Berzelius then demonstrated that if, instead of using a wooden trough, the copper itself be made into cells, or cups, so as to hold and envelop the zincs, but without touching, this would enhance still further the excellency of the battery. Such galvanic arrangements were for many years exclusively used for all experiments and practice that was ventured upon; but they all possessed one great inconvenience; and that was, that after a very *short* time they lost their power, and finally would cease to act, until they were cleaned and replenished.

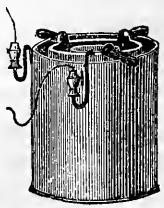


Fig. 41. A Berzelius Battery, separate from the Induction Helix, — commonly called the "Copper and Zinc," or Sulphate of Copper Battery.

To avoid this, M. Becquerel proposed to plunge *each* of the metals into a *special* liquid, — being separated from each other by a porous diaphragm which would conduct and allow a communication between the two liquids. To that end he constructed a battery in a glass jar; he then placed in this vessel a cylinder of zinc, closed at its bottom like a deep cup. In the space between the glass jar and its contained zinc cylinder he placed the acidulated water; but in the interior of the zinc was placed a bladder, or piece of intestine, which contained the copper, together with a strong solution of the sulphate of copper. When the poles of this battery are connected, both the water and the solution of sulphate of copper are decomposed by the electro-chemical action; one part of the oxygen liberated combines with zinc to form oxide of zinc, which at once combines again with the sulphuric acid that acidulated the outer fluid to form sulphate of zinc, while another part of the oxygen combines with hydrogen to form water. Besides this, there is a thin film of copper deposited on the surface of the within copper. Now, it is easy to see that Becquerel's battery would work more slowly, but far more constantly than the voltaic pile or any other battery then known. But the organic membrane was not, after all, very durable; and this was the greatest objection to this otherwise valuable battery.

The *Water battery*, as it is called, came next. It was first prepared by M. Gassiot, and is peculiar for possessing properties of but feeble dynamic electricity, as compared with its static accumulation and tension effects. This is indeed the characteristic also of all so called *dry piles*, which give an electricity in a state of tension alone. M. Gassiot employed glass cells, which were supported upon glass columns so as to render the insulation more complete. Thus he constructed a compound battery of 3520 zinc and copper pairs in as many cells, which were charged only by pure water. This, says M. De la Rive, during the several years it has remained set up, at all times gives electric sparks at each of its poles, (which are also insulated.) The only precaution taken with this apparatus, is to pour water into the cells occasionally, so as to replace that which is lost by

evaporation. In this case, it is the air that is contained in the water that oxidizes the plates so slowly or minutely, that it thus lasts and acts for years together.

In 1836, Daniell conceived the idea of trying various durable partitions to separate the two liquids, as Becquerel had been trying to do. He placed the copper of each pair in a solution of the sulphate of copper, which occupied the larger outer space in the jar, while the zinc was placed in a solution of salt and water, or acidulated water — say sulphuric acid one part, to water twenty parts, or in sea water. He made some diaphragms with felt, some of stout paper, others of very thin wood. Experience gives the preference for a kind of porous *porcelain*, that is durable and yet slowly transmits the liquids for action upon the metals.

In the inner cell, then, — that is, within the porous cell, — he places the zinc in a solution of salt and water, or acidulated water; but the zinc is first coated with quicksilver, which prevents its being attacked *while the poles are not* united by a conductor, and so without diminishing the effect of the battery *while not in use*. But it will be perceived that the decomposition that is brought about is the same as in Becquerel's.

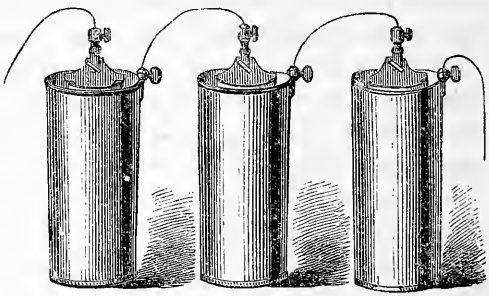


Fig. 42. A Series of three Daniell's Batteries for Galvanism, showing their Connections.

Daniell's battery is now so improved that it is the most permanent and even-working galvanic battery known, and for medical purposes it is invaluable, particularly for the so-called *constant galvanic current*. The arrangement is in large, strong quart glass jars, by using porous diaphragms of pipe-clay cups. Within this porous cup is the solid pound of zinc, say an inch or so in diameter and some four inches long. Then a bit of

sheet copper, say four by six inches, is so rolled and bent as to just drop inside the glass jar, and the jar is then packed nearly full of crystals of sulphate of copper. Indeed, it is better to bruise the sulphate a little in a mortar, so as to work it in without getting it also inside of the pipe-clay cup. The copper is thus buried in the sulphate, and the zinc is placed within the pipe clay; then the whole is filled to within a half inch or so of the top of the porous cup with water. It is better not to fill the inner cup quite as full of water as the outside of it is, for this will allow the battery to get at work within a few hours. Some thirty to fifty of these cups connected *consecutively* form a battery sufficiently powerful for any remedial purposes, and yet, if well managed, will run for a half year in good working order without replenishing except with water. In fitting up this battery, I find it very advantageous to place a strip of stout brown paper or *oil-cloth* about the tops of all the cups, *to prevent* the capillary attraction in the re-crystallization of the sulphate driven on by the process, from running over the outside of the glasses. This has caused me a deal of trouble, as, in the course of every few months, we would find great quantities of the copper solution crystallized all over and between the glass cups; but cementing strips of rubber cloth tightly and carefully around the tops of the cups, so as to be some half inch above the glass, will stop it; (for these cups are without lips or rims,) and then the cloth should be varnished on the outside. This appears to be the most effectual means I can find to prevent this dirty and wasteful inconvenience.

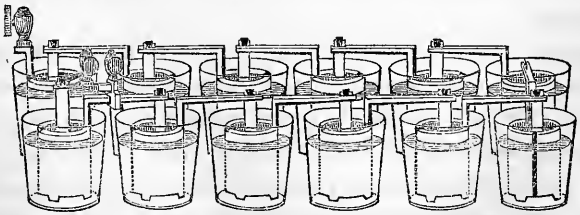


Fig. 43. A Series of Grove's Batteries in a Box, 12 in number.

The next improvement made in the galvanic battery was by Grove; and his is one of the most *powerful* that has ever been constructed. In this battery a small plate of platinum takes the place of the copper, and a strong solution of nitric acid is used in the place of the solution of sulphate of copper. The amalgamated zinc is plunged into a strong solution of sulphuric acid, which is contained within the inner cup of unglazed or porous porcelain. The zinc is amalgamated, i. e., covered with a coat of mercury, by dipping it into a vessel containing a strong solution of sulphuric acid with quicksilver, or by pouring these on the plate, and then brushing it with a tooth brush until amalgamated. Thus the surface of the zinc is cleared by the acid, when the mercury will readily adhere and coat it. In this arranged battery, the nitric acid has the double advantage of containing much oxygen, which first increases the intensity of the current; and second, being a better conductor than the solution of sulphate of copper, it transmits the current through the batteries more readily. Here the hydrogen is not developed upon the platinum, but changes the nitric acid into nitrous acid, and the liquid therefore becomes of a brown color, and then soon passes into a green color, while the surface of the platinum always remains the same — that is, clean. The zinc is oxidized, and sulphate of zinc is found in solution. But after a certain time, this furious battery is fairly *self-arrested* by the further changes which are going on so rapidly in the nitric acid, resulting from the development of hydrogen and heat, until the acid actually enters into ebullition at last, and like the back water of the flooded milldam stops action because there is so much action. In this stage, it is absolutely necessary to stop the action immediately; i. e., to take it apart in order to save the battery.

Bunsen's battery is another powerful apparatus for particular purposes, and this differs but little from Grove's, only as *carbon* is substituted for platinum. It was formerly found that platinum was more negative than copper, that is, still less attacked by the liquid; so is carbon still more negative than even platinum, besides being very much cheaper. In the original Bunsen's battery, there was arranged a cylinder of baked carbon,

open at its bottom and placed in the glass jar, within which was a porous diaphragm of pipe clay, which contained the zinc and dilute sulphuric acid, while dilute nitric acid filled the jar about this large body of carbon. But this has lately been improved, so as to dispense with the porous diaphragm altogether. The author has seen some of these improved *carbon cups*, with *closed* bottoms, so prepared by T. Hall, for the professor of chemistry at Harvard. Some five or six cups produced a heating, chemical, and decomposing power, equal to fifty cells of best Cruikshank's. In this case the carbon cup is fitted with dry powdered carbon, and moistened with nitric acid. We formerly used this battery for cauterizing, as it possesses the most tremendous *quantity* power; but it does not last very long in action, nor is it required to act long for such purposes.

Grenet's battery, for surgeons' use, is here illustrated by Fig. 44, and it is truly a wonderful *multum-in-parvo* instrument for generating and maintaining electric heat. Indeed, this battery is made expressly for this purpose. It yields only *quantity* electricity. The cut shows its structure and appearance when out of its bath. It is composed of some six carbon plates, and eight plates of hammered zinc, amalgamated with quicksilver; each of which is about six inches square, and adjusted exceedingly close together in a frame-work of hard rubber; all the zincs being connected as one folded plate, and all the carbons are likewise connected together as one. Hence it acts as but one grand element.

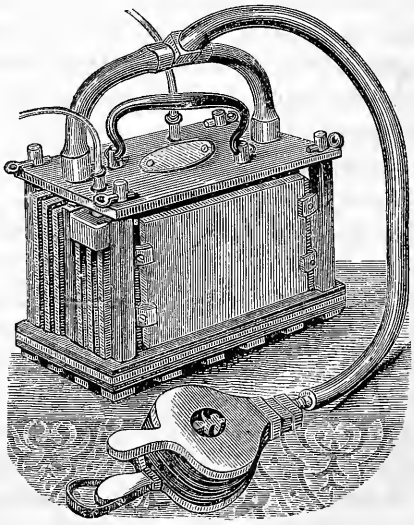


Fig. 44.

A hard-wood box, lined with sheet lead, and having some three gallons' capacity, is provided to receive it. Into this bath-box we pour six quarts of water, and add two pounds of clear sulphuric acid, free from black or straws, and while stirring the water with a strip of glass, pour in the acid gradually. Then add one pound of bichromate of potassa, a good article, coarsely pulverized. Stir well until dissolved and cooled. When all ready for the operation of cauterization, the conductors and the chosen cauterizer being already selected and adjusted, the battery is to be lifted gently into the bichromate solution, and the instant contact is made, the cauterizer becomes brilliantly red-hot. I regulate the degree of heat by screwing fast only one of the conductors, merely holding the other in contact, so as to quickly remove it if necessary, or more lightly touching it to the binding-screw.. As soon as the operation is over — whether five, ten, or thirty minutes — the battery should be taken out of the bath, and immediately rinsed with clear water. It is also well to pour some quicksilver over the zinc plates after each time of using. The solution is to be left in the lead-lined box for future occasions.

After this battery has thus been used a few times, the produced heat is less. In this case, or if a more severe operation is anticipated, fix on the elastic tubes and adjust the bellows, so that an assistant can force air to the bottom of the battery, which is perforated from an air-chamber. The air is thus forced down, and up through the solution, aerating it and causing a more rapid oxidation. Thus any degree of heat, even a white heat, may be obtained, regulated and maintained for a good part of an hour. The battery is then readily cleansed, as above directed, and the solution is to be renewed when exhausted. Phile Grenet, 14 Rue Castiglione, Paris, provides this beautiful apparatus, as also a smaller one for faradaic currents.

Thomson's constant copper-carbon battery is intended to be an improvement on Daniell's and Smee's batteries, as *a permanent primary compound battery*. It is called "*the copper-carbon element.*" Usually zinc officiates as a positive element. In the Thomson's battery, *copper* takes the place of zinc, which is placed in dilute sulphuric acid (one part to four of water) as

a positive element; and as a negative element, *carbon* is used, in a mixture of bichromate of potassa, sulphuric acid, and water,—twelve parts of bichromate, twenty-five of sulphuric acid, and one hundred parts of water. The electro-motive force of this battery is nine times that of Daniell's battery; but it is expensive.

The Iron battery, a modification of the *Bunsen*, is simple, inexpensive, and yet most powerful. In the iron cell, outside the porous, is nitric acid; while within the porous cell is dilute sulphuric acid, into which is plunged the amalgamated zinc. From a half-dozen to a dozen such quart cells you can obtain great quantity and intensity, for electro-cautery.

Smee's battery is the most clean, and one of the most permanent and economical arrangements we know of. This is arranged in a quart or half-gallon glass jar, by mostly filling it with water acidulated by one tenth or one fifteenth part of sulphuric acid. Into this are plunged two flat, square plates of zinc, say four by six inches, and one half inch thick, and coated with mercury, which are suspended from the top. Between these there is arranged the thin plate of platinum or platinized silver. This apparatus can remain in working order for a month, but if much used should be overhauled once a week; that is, the zinc plate should be new coated with quicksilver, and if that is well attended to, for dentists and other office use it will wear a year or more.

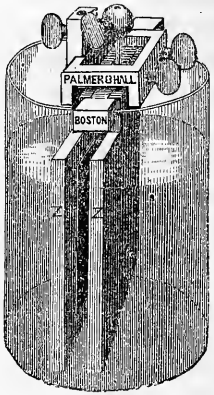


Fig. 45.
Smee's Constant Battery.

Fig. 46 is a view of *Humboldt's battery*, consisting of one primary element. This is something new, although the *principle of its action* was known to the great baron and philosopher nearly seventy years ago; but the term *Humboldt's battery* originates with the author. The convenience and usefulness of this very cheap, portable, durable, *and least troublesome of all gal-*

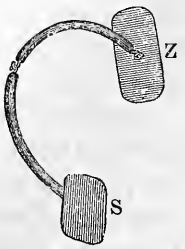


Fig. 46.

vanic arrangements, and its very peculiar adaptation, under frequently recurring circumstances, for the treatment of a given class of cases, must gain for it a prominent place among the more *practical and reliable* of our best electro-therapeutics.

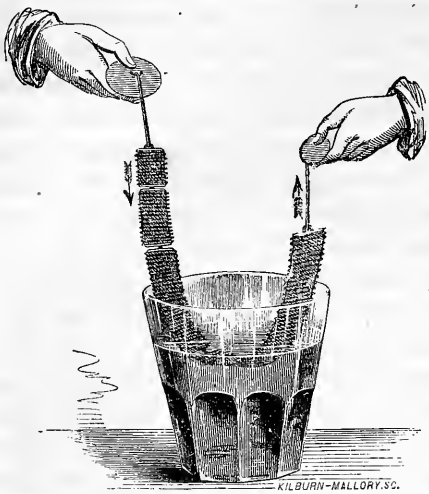


Fig. 47.

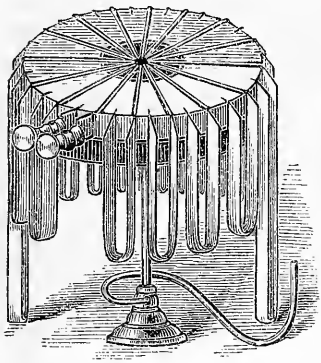
Fig. 47 is a view of *Pulvermacher's portable chain battery*, for medical purposes; consisting of 1, 10, 25, 50, or 100 adjustable elements. It is better known in Europe, and is a very remarkable miniature voltaic pile. The *pairs* of this consist simply of a piece of hard wood, around which is coiled a zinc wire, that terminates at one end with a hook or eye. Then there is coiled between the zinc coils a brass wire that terminates at the other end of the link in the same manner. This forms an element. These are linked together like a chain, the brass end of one into the zinc end of the next, and so on for sixty or one hundred and twenty links, which terminate with a brass buckle and belt at one end, and a silver plated buckle at the other, for fastening it about the body or limb; or, according to Pulvermacher's directions, "Apply the gold buckle over the spine, and the silver buckle over the seat of disease." Besides, there is a clock-work for breaking the current, &c. But this voltaic principle, correct as it certainly is, for economy, becomes a failure in practice — first, because of its frail construction; second, because of its electrode arrangements being intended for empirical application, rather than for scientific and skilful manipulation.

The *Electric Moxa* of Dr. Golding Bird is admirably made by the Humboldt battery, heretofore described. He advised the making of two blisters, by blister-plaster, in the ordinary way; the one above, the other below, the spot that is to be affected.

The silver plate is to be placed upon the *lower* denuded blister, while the zinc plate is planted also over the upper denuded blister, when the connecting wires from each are brought together, and twisted into secure contact. But the joined conductor must be perfectly insulated from the skin and wet cloths. The blister, over which the zinc plate was bound, is found, in the course of a few hours, to be coated with a whitish-looking film, as if the chloride of zinc had been applied to it. In forty-eight hours an eschar is produced, which begins to separate some four or five days afterwards. The eschar is produced by the chemical action of the continuous current in decomposing the effused fluids on the surface of the blister. The chloride of zinc thus gradually formed, and as gradually applied, by the electro-chemical action, produces the new sore that will now freely discharge pus when a common poultice is applied to it. While this process is going on the patient is *usually* quite free from pain, but the author has known some decided exceptions. Where it does prove painful it had better be at once removed, for after a little time it can often be reapplied without the suffering. Dr. Bird advises the blisters to be the size of a half dollar or dollar, and to always apply the *zinc plate* (which is of the same size of the blister) *nearest to the head of the patient*, while the silver, which is the same size, is *farthest* from the head, and nearest the extent of the extremity, as, for instance, of the hand or foot. Over each plate, water or salt-and-water dressing is applied, and, above this, oiled silk or rubber cloth, merely for the purpose of retaining the moisture; while flannel or warm clothing covers over the whole.

Thermo-electricity means, simply, an electric current produced by heat (instead of acids) acting upon certain metals. It can now be produced in an active current, like galvanism. In effect it is chemical, magnetic, and physiologically effective, precisely as galvanism. Hence it can be used as a compound primary battery, or as a single cell for working a helix for medical purposes, as also for electro-plating and telegraphing. In this matter our knowledge dates back only to 1832, in which year Professor Leebec, of Berlin, discovered that if a bar of one metal be

soldered to a bar of another metal, and bent or placed in such wise that the two bars form the letter V, and the two upper extremities of the two limbs be united by a piece of wire, — if, then, the point of junction of the two bars be brought, either by heating or by cooling, to a different temperature from that of the rest of the circuit, an electric current will be manifested. By connecting together, in a certain order, a number of such pairs of bars, he first constructed a thermo-electric pile, or battery, which was then modified and multiplied by Nobili and Melloni, resulting in that most exquisitely sensitive little instrument known as Melloni's thermoscope, — a test for heat, — which is affected by the warmth of the hand, simply, while several yards from it.



This figure represents a new thermo-electric battery, invented by Mr. M. G. Farmer, an electrical engineer of Boston, who has bestowed years of labor upon this subject; and he has marvellously succeeded. He has arranged a series of diagonal blocks of an alloy, (something like German silver,) with strips of copper and mica, in a circle, so as to be steadily and very economically heated by a flame of gas, or spirit-lamp. These *clean* and *durable* little batteries are abundantly able to work any ordinary medical helix, and with prodigious power when required. Moreover, from it may be obtained the effects of a Grove half-pint cell — an active primary current.

All that is required is the flame of gas or kerosene lamp; and in one minute it is in action. No solution or acids, no cleaning, ever required. The first cost is only from five to twelve dollars, and it is a neat and durable office fixture for physician or dentist. Manufactured by Chamberlain & Son, Washington Street, Boston; also by Smith and Butler, 449 Broome Street, New York.

Electrodes, platinum points, needles, and cauterizers for sur-

geons' purposes, can be had of electrical instrument makers: T. Hall, 15 Bromfield Street, or Codman & Shurtleff, 13 Tremont Street, Boston; or of Chester & Co., 104 Centre Street, or Tieman & Co., New York; and of surgical instrument dealers in Philadelphia, and elsewhere.

Static Electricity as it relates to Medicine.

We now know that we cannot classify all bodies into *perfect conductors* of electricity, and into *perfect insulators;* or, in other words, we cannot say of silk or metal, that the one never conducts in any case, or that the other conducts perfectly well under all circumstances; therefore the *term* electric conductibility is not absolute. The metals are almost perfect conductors; yet they present among themselves, as we have already observed, a difference in degree of conductibility; also the same metal or body conducts better or worse, according to its *dimensions* and its *temperature*.

Generally we call all bodies *electrized*, whatever they may be, which have been put into communication with an electrized body; but strictly so speaking only when they thus show an attraction at a distance upon light bodies. Therefore in Static Electricity we are taught to observe, —

1. That there is an *attraction* between an electrized body and one that is not electrized.

2. That there is *repulsion* between two bodies electrized by the same source of electricity.

3. That there is an *attraction* between two bodies electrized, the one as by glass, and the other as by wax; glass acquiring by friction *vitreous* electricity; wax acquiring by friction *resinous* electricity; the former, or vitreous, is termed *positive electricity;* the latter, or resinous, is termed *negative electricity.* When these reunite, and neutralize, either through the air as a spark, or insensibly, or through a conductor, the electricity is then said to be in the *dynamic state;* i. e., during the *instant* that this marriage is going on. This is also termed the *electric discharge.*

To be understood, this denomination of *dynamic* is given to that state of movement in which the two electricities are supposed to be, when travelling towards each other to neutralize, in contradistinction to the *static* state, or that of rest, as where these two different electricities are found when they are separately accumulated, on insulated bodies. This latter state is also called *electric tension.*

We see, then, that dynamic electricity may be only *instantaneous*, or it may be *continuous*. In the preceding case it was instantaneous, and done. But suppose one ball to be in communication with a constant source of positive electricity, while the other ball is connected with an equally constant source of negative electricity; the two electricities being constantly renewed as fast as they are neutralized, there will be a continuous succession of sparks, if the balls or electrodes are brought only close together; but if so as to touch each other, then there will be between the two ball electrodes a continual, uninterrupted neutralization, or, in other words, a continuous reunion of the two electricities. This is denominated *the continuous dynamic state*, and also called the *electric current.*

Electric Conduction.

The property which is possessed by most bodies, and by metals in particular, of more or less readily acquiring and propagating through their whole extent the electricity that is possessed by that part of an electrized body with which they are in contact, is termed *electric conduction*, and such materials are called *conductors*. Those which do not possess this property are called *insulators*. The human body, ordinary wood, animals, vegetables, and most minerals are conductors; while amber, wax, glass, baked hard wood, fur, gum-lac, resins, and a majority of crystals, as also silk, oil, rubber, and gutta percha are *non-conductors*, or, in other words, are insulators. The earth is our largest conductor; the vast extent of atmospheric air over its surface, when dry, is our largest insulator. The *diamond* is the most perfect insulator, while *silver* is most nearly a perfect conductor.

The conductibility of bodies for electricity, which are so reckoned, is not, however, an absolute property, for there is every grade of difference observed in different bodies; and these even vary in themselves at different times. Water is a conductor, but *dry* ice is a good insulator. Glass is reckoned a most excellent insulator; but if it is damp, or is drawn out into a slim rod, or is heated to redness, it becomes a good conductor. Wax and tallow become conductors by melting them; but the metals, on the contrary, *do not* conduct so well when they are heated.

The dry atmospheric air, being an insulator, prevents electrized bodies losing their electricity. Were the air a conductor, it would cause the electricity of every insulating body to be dissipated into the whole mass of the atmosphere, as does contact with the earth. This does take place when the air is moist, or where the apparatus is colder than the air. Therefore it is necessary to have a dry atmosphere, and a machine free from humidity, to make experiments or practice succeed well with friction electricity.

It is necessary to be mindful, that, if any electric current of a given quantity and intensity is made to pass through several different wires, of the same sample of metal and make, and same diameter, but of different lengths, we shall see that the current loses power in proportion to the length of the wires tested. If, now, the current is made to pass through wires of exactly the same metal and length, but of *different diameter*, the power is greater in proportion to the diameter of the wires. For instance, a copper wire that is a hundred feet long and the tenth of an inch in diameter, will offer the same amount of resistance as another copper wire that is two hundred feet in length and only one fifth of an inch in diameter. The conductibility of bodies, therefore, does not depend upon their chemical nature only, but also upon their *form*. Nor are there any absolutely perfect conductors of electricity. Indeed, it may be said that *all bodies* through which a current may be directed offer a certain greater or less resistance; and hence diminish its intensity according to their chemical nature and form.

If a galvanometer be placed between the shortest poles of a

voltaic battery, we see the astatic needle deflected to a certain degree by the passing current. If we now lengthen the conductors by interposing copper or even silver wire of a given length, and then again of twice that length, and then again of twice the length of the latter, we shall find from these experiments, that the needle of the instrument is less and less deflected, according to the length of the conductors, although of the very best material. The human living body conducts all electric currents ten to twenty times better than pure cold water. This is supposed to be on account of the warm salt water it contains. But I am more and more inclined to believe that this is owing to the arrangement of these different fluids in the different cells and tissues of the living organism, which are separated only by the thinnest membrane, and being provided with nerves, not only have a *tendency* to electric action, but possessing an *actual*, *perpetual* minute action, which, to my mind, serves for the artificial current conduction, much as Professor Morse's registering battery helps the working of the wires; perhaps more, as the aurora borealis helps the conductibility of the telegraph wires.

The epidermis is, in this case, probably, the greatest hinderance to all currents of electricity; but this can be greatly counterbalanced by *wet* electrodes. There is an absolute difference in the conductibility of different persons, and even of the same individual at different times. In a group of persons, a single one may be struck by lightning, while all the others remain untouched. But this is not as yet satisfactorily explained. The human body, then, after all, is not in effect a good conductor of electricity, as can be proved by the galvanometer. To test this, the resistance is first determined of the given entire circuit, of say a bearable, but appreciable battery, such as twenty to thirty Daniell's elements afford, by bringing together the two poles in good contact, including nothing but the galvanometer. The degree of resistance from the connecting wires of the batteries, the conductors, and the instrument together, as marked on the dial, is first noticed, and taken for unit or zero. Then the limb or individual is interposed between the wet electrodes, which

must have large and complete contact. Let this be repeated first without, and then with the interposition of the portion of body to be tested, and a very exact relative degree is obtained of the resistance of that given organism.

Direction of the Current.

In the original *voltaic pile*, the positive pole, we have seen, is at the top of the pile, which is zinc; while the bottom of that pile is consequently positive, which is copper. This *law* holds good with all dry, or moist, piles and batteries; as by the law of electro-motive force, positive electricity is driven from the copper to the zinc, and hence the zinc is forced to be positive and the copper negative. *But, mark — this is not true* of our ordinary liquid batteries; for where the metals are plunged into separate vessels, as is the case in the constant batteries, the direction of the current is exactly the reverse. In these batteries, *the positive current travels from the zinc* through the liquid of the battery to the copper, and then from the copper to the zinc of the next pair, and then through that liquid to the copper there contained, and so on through all the series of pairs in the cups or jars of the compound battery; so that the copper is always the positive pole in these constant batteries, and the zinc of course is the negative pole. This is even so in a Berzelius's or a Smee's battery, where there is a single pair in a single liquid. Therefore, in the Berzelius's and Daniell's batteries, the positive pole will be formed by the copper; in Grove's or Smee's batteries, by the platinum or silver; in Bunsen's battery by the carbon; while the zincs form the *negative pole* in each and all of these batteries.

To fully appreciate the kind, nature, and difference of battery or chemical electricity, and to have a rational view of these currents, we must set out with this *law*, namely: where a liquid attacks a metal, the liquid becomes charged with *positive* electricity, and the attacked metal becomes *negative*. The positive of the fluid is at once taken and conducted by the less oxidizable metal that is plunged in the same, and thus conveyed along the conducting wire, back to the oxidizing negative plate in the

battery. If a vessel is nearly filled with acidulated water, and into it we plunge a plate of very oxidizable metal, such as zinc, for example, and also another plate that is much less oxidizable in that liquid, as platinum, and then we unite the two dissimilar metals merely by means of a wire brought up out of the liquid, then the positive electricity that is acquired by the liquid, from the effect of the chemical action, is able, by traversing the connecting and conducting wire, to return and reunite with the negative electricity that the attacked metal has retained. For thus the greater portion of the two electricities, negative and positive, become neutralized through this peculiar process and order, instead of taking place locally, directly at the place of contact of the liquid with the metal that is oxidized, and which Faraday has termed *local action*. Here, then, we see the *rationale* of the electric current or *stream* of the battery with which we shall have so much to do. And this peculiar association or relation of any two dissimilar metals in a liquid, whose power for oxidization and conduction is peculiarly or exclusively for one of the metals rather than for the other, is termed a galvanic pair or battery; and when a number of these are connected, they are then termed a *pile*, or so many *elements*, or a "*compound battery*."

Philosophers teach us that we may also regard the two metals of any voltaic or galvanic pair as separately, but mutually, giving rise to two opposite and unequal currents, one of which — and it is always that arising from the metal most attacked — is the more intense, while the other, arising from the metal least attacked, is the more feeble; that each of the two metals also serves as a conductor to the current of the other. The current, then, that is accumulated is the difference between the two partial and unequal currents, as they would be perfectly null if these two opposite and simultaneous currents were absolutely equal — a condition, as M. De la Rive says, next to an impossibility, even if we employ two metal plates as similar as can be in every respect.

It is, therefore, a *law that the metal of the battery that is most attacked determines that current direction.* But while we attempt to establish in our minds the *first fact*, that the

metal most attacked is the *positive*, and the *second fact*, that the metal least attacked is the *negative*, we must not lose sight of the *third fact*, that the positive electricity comes out of the battery by the negative or copper metal after having passed through the liquid of the battery, and consequently the other, or *negative* electricity, comes out by the positive or zinc metal, so that in these batteries the *zinc pole is negative* while the *copper pole is positive*. Besides, we should take the terms *positive* and *negative* simply in the sense of *electro-motive power*, — the positive as predominating over the negative, and constituting a prevailing stream or current. But we must also recollect, that although it is true that the metal most attacked is the starting point for the current direction, yet the mere galvanic series of metals do not of themselves and under all circumstances determine the route of the current *absolute;* for this is likewise dependent upon the *nature of the liquid* that is employed as an exciter or oxidizer. Faraday found a very curious and interesting *variation* of the current when he placed a galvanic pair of copper and silver in a solution of sulphuret of potassium; the current first setting out from the copper, the silver is not the least tarnished, and soon the action dies down to a low degree. But this is soon seen to be followed by an increasing action that is now on the silver, which gives rise to a current running in the opposite direction, while the silver is becoming more and more coated with the sulphuret; and at the same time the film that was at first formed on the copper is as rapidly dissolved off; in a few minutes more and the needle of the galvanometer drops to near zero, but as soon again begins to rise, reversed, showing an increasing but changed current direction, and the copper again becomes positive, and coats over. Thus the chemical action and the direction of the current change simultaneously.

Quantity and Intensity.

Electricity, when in the current form, has two very distinctive and important characteristics, which must never be unheeded or

confounded. I refer to *quantity* and *intensity*. There appears to be no actual relation between the vivacity of chemical action and the preponderating intensity of electric signs. From this it does not follow that the *quantity* of electricity that is set free is not in relation to the given chemical action. On the contrary, these two respective quantities are in exact proportion to each other. Then it is rather the *nature* of the chemical action than the vivacity of it that determines the characteristic of *intensity* in the given electric manifestation. There cannot be intensity, however, without some degree of chemical action; but the amount of such action graduates the amount of electricity: because this kind of electricity possesses the characteristic property and power of overcoming a great resistance, it was therefore first termed by Faraday electricity of intensity, in contradistinction to electricity of quantity.

These two different forms of electricity from the various galvanic pairs have very different physiological effects, and therefore require to be particularly observed in all therapeutic employments of the current. How, then, can this intensity of the galvanic current be reënforced without a corresponding increase in the quantity? One way to do this is by simply *adding similar pairs in succession, and so connecting them that the positive of one is in metallic contact with the negative of the next*, and so on through all the series, no matter how small or great the number. M. Gassiot, by a series of most remarkable researches with his *water battery* of 3520 galvanic pairs insulated, discovered in this connection, that the more powerful the mutual affinity of the elements that compose each battery, the less number of such are required to produce the same great effects of tension. He found, by well insulating one hundred of Grove's batteries, a *tension* accumulated at the poles quite equal to that of the whole water pile of 3520 pairs. But to test the *relative* tension of such an arrangement, that is, with the same given deviation of the galvanometer, it is necessary to use the electrometer to detect directly the tension, or by using the rheostat to detect the amount of resistance that is overcome.

The law of electro-chemical equivalents of a single galvanic

pair was first pointed out by Faraday. M. Matteucci next gave the equivalents for a pile or series of batteries, by using as a good electrolite a solution of the sulphate of copper. If the battery, for example, is composed of ten cups and pairs, then ten equivalents of zinc must be consumed to decompose one equivalent of water — thirty where there are thirty cups, and so on. It would seem, then, to be much better to employ only one or two cups and pairs, since to produce the same effects, where no great resistance is to be overcome, we can save some ten to thirty parts of zinc. But we find that the decomposition is less free, and also the electrolite *requires* a current possessing a certain degree of intensity, or, what amounts to the same thing, having an electro-motive *force* of a certain power, which can best be given it by multiplying the number of cups. So, also, as regards great resistances that are to be surmounted; M. De la Rive says, "When a current is called upon to traverse a long telegraph wire, it is necessary for it to be accomplished to use a numerous succession of cups, for if it were attempted to be produced by only one or two cups and pairs, no matter how great their size and power, it would not have sufficient *intensity* to overcome the resistance of the long wire."

We must also be reminded, that the *size* of surface of the galvanic pair or pairs is able to influence *only the quantity* of chemical action exerted in a given time; but that it can in no way modify the electro-motive *force* of the pair or pairs, nor will there be the capability of the produced electricity for surmounting a given resistance; for where this resistance exceeds a certain bound, itself limits the quantity of efficacious chemical, or catalytical action, by the very deficient quantity of electricity that can be transmitted in a given time, and hence renders useless the increased surface of the plates beyond a certain size, which is in relation to that of the resistance and kind of work to be done. The *quantity* of the current is in proportion to the *size* of the pair; the *intensity* of a given current is in proportion to the *number* of pairs.

On the whole, then, we see that the law of electro-chemical action, as far as it concerns the electrolysis placed in the given

circuit, exterior to the series of pairs, i. e., placed between the poles, is a *general law*, and applies therefore equally well to what takes place in the interior of the battery, as through the route of the conductors, and the body embraced between the poles. The galvanic *circuit* of a series, when closed, is indeed but a circle composed in parts and by bits of conductors, united end to end in the series of the battery through which the current circulates, in a manner perfectly uniform and identical. In this there is brought about a change, by a succession of polarizations and recompositions of the contrary electricities of the consecutive molecules, in such a way that if the current encounters *resistance* heat is evolved; if the molecules are compound, and the current is persistent, then there is chemical decomposition. All these effects are capable of being equal in all parts of the same circuit or circle, (for such it is,) including the contents of the cups themselves, on the one side, and no less so the matter included between the electrodes that is to be operated upon, on the other.

It is then understood that there is a marked difference between the quantity of electricity *produced*, and the quantity that actually *travels* the circuit, or, in other words, that penetrates and passes through the object of work that is between the poles. This is always more or less retarded, or facilitated, aside from the power or kind of battery, *according to the resistance* or poor conducting property *of the given object* that is acted upon. The result is necessarily different. There cannot be a current, as we have shown, without some degree of both quantity and intensity; but we now refer to these two relative properties. A single pair of almost any battery gives a quantity current, i. e., more of the character of *quantity* than of *intensity*. The former has the property for chemical decomposition, the latter for overcoming the resistance of an indifferent or bad conductor. Generally, we can increase the quantity by the larger extent of metal surface in the one battery cup; also by the kind of metals that constitute the pair, or by the increase of acids or salts in the liquid of the battery; in a word, by extensive and rapid oxidation or chemical action in the liquids or metals in a given time. But the *intensity* is increased, as we

have shown, by the increase of number in the pairs that compose the compound battery, but without an increase of size.

We conclude, then, that a galvanic current is great in *quantity*, and capable for chemical action, if produced by a single pair or more, much in proportion to the size and action of the pair if connected with a thick wire. The density, tension, and intensity of the current for passing over and through poor conductors will be much in proportion to the number of the series, and the smaller size of the wire connections and conductors. The efficiency of every battery depends upon good contacts. This is mentioned *particularly*, because the greatest and most frequent failures, partial failures, or differences of results, arise from this want of exact care.

There is another method for increasing the electro-motive force of even a small galvanic current of a single pair, as well as some modified *kind of intensity;* but this must be reserved for the next chapter.

Derived currents, spoken of by authors, are those that are obtained by a sort of *by-path*, namely, when the conductor of a closed circuit is conveying a galvanic current, this is termed the *primary current.* If, now, we add a short and nearly parallel conductor by making contact at its metallic ends, on the route of the primitive wire, a portion of the current will pass along the second wire, provided it is not much longer nor smaller, nor otherwise a poorer conductor, than the primary wire. And this is termed a *derived current.* The author, however, finds no use for such in therapeutics.

Electric heat is produced in the same way as electric light, by a rapid or extensive chemical action, in a single or compound galvanic battery; but instead of using both great quantity and intensity, we require only *quantity*, with very little intensity. Electric light cannot be, without some considerable heat; nor can we obtain electric heat without some considerable degree of light. This, however, is never a drawback, while it is often of the greatest advantage, as when required to use electric heat for cautery in deep cavities, as in the throat, rectum, or vagina. See *Electric Cautery.*

Heat can be produced by an obstructed or retarded current

of electricity, as, for instance, where a large quantity current is led by a wire too small to convey it all freely, or through a poor conductor, as *platinum*. It may be evolved by the disruptive discharge between the two poles of a galvanic battery, where disintegration is effected, and the particles of one pole pass over to the other pole, with the evolution of *intense heat* and light. If we but coil a fine bit of platinum wire into a small spiral, it may be heated, even *instantly*, to a white heat, by making contact with a galvanic battery of large-sized cups, of quick action, and few in number. Thus it can serve the most perfect office of a *cautery* that is known in surgery. For this purpose, as we have elsewhere explained, it takes some half dozen half-gallon jars of a Bunsen or Grove's battery. (See *Grenet's Battery.*)

It must be borne in mind that when using a compound galvanic battery of high series for remedial purposes, that the law of this current is *heat*, in proportion to the power of the current and the obstacle opposed. This capability of such a current is aroused, then, not only by a small or poor conducting wire, but also by passing through a portion of the human body, as in ordinary treatments. Therefore the operator must know that if the electrodes are retained for some time on the same spot, while a large current is flowing, there will be danger of producing a slough, simply from cooking the flesh by electric heat. Let the same current pass through a small quantity of water, as in a glass tube, and it is seen to be not only rapidly decomposed, but it also boils, and that instantly and furiously. But there need be no kind of danger of this accident occurring, except from sheer ignorance or carelessness.

Faradaic Batteries and Apparatus.

Induction electricity, — i. e., currents obtained by the now well-known laws of induction styled galvano-magnetism, magneto-electricity, electro-magnetism, &c., — when used for or spoken of in connection with medicine, the author has termed *faradaism.* This sort of apparatus we term *faradaic*, (pronounced *faradic,*) or *faradaic machines.* The peculiarly intense current of inter-

rupted electricity thus produced we term *the faradaic current.* The application of such currents is termed *faradaization.*

Professor Faraday was not the first discoverer of this manifestation of electricity, but he was the inventor of this class of electric apparatus. Therefore, in the first edition of this work, which appeared in 1860, the author, first of all, on page 141, blended the name of Faraday with both the cause and effect, so as clearly to distinguish this peculiar kind of machine and current from every other apparatus and manifestation of electricity. Thus *faradaic*, in contradistinction to *galvanic*, and *faradaism*, to be distinguished from *galvanism*, that we may no more confound them. We must carefully discriminate the primary current as differing widely *in action and result* from the secondary or induced current, in all electro-physiological and therapeutical operations and *reports.* Faradaic machines, faradaic currents, and faradaism are now becoming familiar terms, and being adopted by medical men in all parts of the world.

The term "*faradaization*" the author does not claim. Dr. Duchenne, of France, had long time ago already connected the name of Faraday *with a peculiar method of application* of these currents for remedial purposes. Hence "*faradaize*," "*faradaization*," and "*localized faradaization*" are of this origin, and are also being adopted as convenient and definite terms, in some late medical literature, — a just tribute to the great benefactor, — and will become points of accuracy for all future electro-medical statements.

Induction Currents.

For a long time philosophers were impressed with the analogy there seemed to exist between electric and magnetic phenomena. There were manifested two magnetisms — the north and the south poles; as there were two electricities, plus and minus, or positive and negative. Indeed, very many of the phenomena of electricity in motion, are closely related to magnetism. The attractions and repulsions manifested between the two magnetisms, as between the two electricities, are according to similar laws.

In 1819 Professor Oersted, a Danish philosopher of Copen-

hagen, made the first scientific demonstration of the action of electricity upon a magnet. As Dr. Benjamin Franklin had demonstrated the identity of the lightning of the clouds with the spark of the friction machine, — which, indeed, had long been suspected and as much doubted, — so here was actually proved that which had been so long suspected and sought for by some, (while doubted and scouted by others,) but not where, and in the way, it had been thought to exist. The finding of M. Oersted was, that electricity acts upon a magnet, and that a magnet, in its turn, acts upon electricity; but *only* when the electricity is in motion.

The following is his fundamental experiment: When the poles of a galvanic battery are closed, so as to make a continuous conductor, and if this wire, while the current is traversing it, is placed either above or below a magnetic needle which is freely suspended and parallel to its direction, the needle is immediately deviated, and all the more considerable as the galvanic current is more powerful. It tends to place itself transverse and perpendicular to the conductor wire of the battery — a position it nearly attains, provided it is near, and the battery current is sufficiently strong. In fact, the extent of the deviation of the needle is directly proportional to the power of the battery, and inversely proportional to the distance between the needle and the wire. But if it is a common magnetic needle, it will not be deflected so far as to assume a position exactly at right angles with the conducting wire, on account of the influence of the earth, which still acts upon the needle, and tends to draw it back to its natural magnetic meridian. Therefore it will come to rest in a place between the two forces, according to the predominance of the one or the other. The direction in which the deviation takes place depends upon two circumstances: the first is, the *position* of the conducting wire of the battery in relation to the magnetic needle, as it may be above or under it, or it may pass it perpendicularly with an up-running or down-running current; the second condition is, the *direction* of the current.

Ampère drew the attention of natural philosophers to the fact that the earth's magnetism prevents the magnetized needle from

entirely obeying the influence of the electric current. To obviate this he proposed the *astatic needle*. He first, or M. Nobili, constructed this by placing a second needle above, parallel with, and near to, say within a half inch of, the traversing magnetic needle. The upper needle, being made fast on the same centre shaft with the first, moves on the same pivot; but its polarity is *reversed* as to the other, so as to neutralize its directive tendency in respect to the earth, and so that it shall remain at rest in any position. But the two needles cannot be *perfectly* alike in all respects, and possessed of absolutely the same quantity of magnetic power, and therefore the globe will always have some degree of effect upon the static needle. Yet it is certainly proved that the electric current does, more promptly and completely, control a needle so prepared as to be *double* and reversed than the *single* magnetized needle.

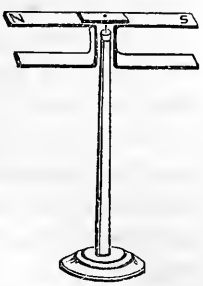


Fig. 48. Astatic Needle.

If the conducting wire of the galvanic current is placed horizontally below the needle so as to run north, the north pole of the needle is instantly deviated eastward. If the electric current is now reversed so as to run southward, the north pole of the needle flies to the west. But if now the conducting wire is raised above the needle, and still horizontal, the deviations of the needle always occur in the contrary direction.

While M. Ampère took up M. Oersted's discovery to generalize and extend it, M. Arago was looking into this matter, and soon showed that an electric current not only acts upon a magnetized needle, but that it also acts upon all magnetizable bodies, even when they are not magnetized. Having coiled a small, soft iron wire, he found that when this wire was being traversed by a strong electric current, it acquired the property of attracting and retaining around it a certain quantity of iron filings, much like a cylindrical envelope, but that the instant the current ceased to pass the filings fell off; but as soon as the current run again, the wire took them up again.

M. Arago further showed that the powerful charge of a Ley-

den jar even, may magnetize a steel needle, if placed in the interior of a helix made of metal wire through which this discharge is made to pass. Sir H. Davy soon afterwards discovered that we can magnetize common sewing needles by merely rubbing them back and forth transversely over a rectilinear wire *while* it is being traversed by the electric current of a battery. These experiments prove that the electric current impresses upon battery conductors, that are thus traversed, properties perfectly like those of magnets, not only those of magnetic bodies: but in fact it actually magnetizes those thus traversed.

M. Ampère found, besides, that a galvanic current not only acts upon a magnet, but that it also exercises an action upon another contiguous electric current, which may be stated thus:

If two portions of straight, movable wires have constant galvanic currents coursing through them, they are then mutually *attractive* and *attracted*, while the current is still moving in the same direction; but if one of them is reversed, so that they run in contrary directions, then they are *repelling* and *repelled;* and this is not instantaneous, as with static electricity, but is continuous as long as the current continues to traverse the conductors. Thus the ascertained action of an electric current upon a magnetized needle had furnished the means in every respect for determining the existence, and for appreciating the force, of any sort of electric current. Immediately M. Schweigger, a German philosopher, applied these principles to the construction of the first galvanometer multiplier, which was employed by M. Nobili in his wonderful electro-physiological researches. M. Dubois-Reymond then constructed on this same principle a galvanometer of the utmost sensitiveness, and as remarkable for its accuracy, by employing more than 24,000 elliptical convolutions of insulated fine wire, by which he was enabled to detect the presence of electric currents even in almost all the tissues of the living animal body; and by this superior aid he arrived at his fundamental and special laws in electro-physiology.

Very soon after Oersted's discovery, Arago demonstrated that if a copper wire that is well covered with silk thread and

varnish be rolled into the form of a helix around a bar of soft iron, and an electric current is then caused to pass through the wire so coiled and situated, *the soft iron becomes a powerful magnet*, and remains so as long as the current runs. He showed that it is with the greatest rapidity that soft iron is magnetized and demagnetized by the electric current. Such temporary magnets are termed *electro*-magnets, in order to distinguish them from permanent magnets of steel. Thus on, he showed that the electric current imparted a magnetic property to pieces of soft iron *temporarily*, to steel *permanently*, also to other bodies that did not possess it previously.

The term "*electricity of induction*" strictly means the development of electricity by the influence of other electricity in proximity, or else by means of magnetism. That developed by the influence of the former is called electro-static or electro-dynamic induction, and also *electro-magnetism;* that of the latter is termed magneto-electric induction or *magneto-electricity*. When two *helices* (which are, indeed, but coils or bobbins of wire in which galvanic currents are then flowing in the same direction) are placed end to end, they attract each other; but if one of them is reversed, so as to give opposite currents, repulsion is manifested. So, according to Ampère's theory, when two permanent steel magnets are placed end to end, there is attraction or repulsion on the same principle.

If we take a Smee's battery, or a good sized and active sulphate of copper battery, and connect the poles by a *short* copper wire, no spark is usually perceived when the connection is formed or broken, but, if any, never at contact, and only very faint when opened. But if this connection wire is replaced by one that is fifty or a hundred feet long, the spark appears much brighter and more certain; but if we *coil* this wire as on a spool, then the spark is still more vivid and more uniform. The most advantageous length of wire coil for producing the greatest spark depends upon the diameter and quality of the wire, and also upon the quantity and intensity of the battery. If a battery of higher intensity is employed, such as Grove's, then the wire may be much further increased; but the greater the

quantity of the electric current, the *shorter* or *larger* must be this wire in order to transmit the whole of the current, and to obtain the greatest effect or the brightest spark. By means of a wire some hundreds of feet in length, a slight shock may be felt from a single pair at the moment of opening the circuit, if its poles are arranged as moist electrodes, and are held in the hands. By testing it through the tongue, this intensity increases until the wire is some six or seven hundred feet long: by using a number of pairs, or even a smaller size, a greater length of wire in helix can be employed for shock or spark with greater effect. The maximum effects of a single small battery are, of course, less than those of a large one, and if the requisite length of wire for the given battery current is exceeded, the effects are diminished.

In 1831, Professor Henry, one of our American philosophers, was the first to discover this peculiar action of a long conductor when extended, and also, when *coiled into a helix*, as so modifying or *increasing* the current of a single galvanic pair *at the moment when it ceases to flow*. He was the first to employ coils of *metallic ribbon* for obtaining sparks and shocks from a single galvanic pair. By this means the brilliancy and power of the spark are very greatly increased whenever the circuit is broken.

Thus far had this branch of science advanced when in the same year Professor Faraday, of England, discovered that an *electric current*, as well as a *magnet*, *is able by induction to develop electric currents* in conducting wires. This he proved by placing on an insulating plane two parallel conducting wires very near to each other, but without touching. The two ends of one of these wires are connected with the poles of a galvanic battery, so that it in fact becomes the connecting wire between the two poles of that battery. The two ends of the other wire are connected with the extremities of a sensitive galvanometer, simply to judge of the electric movement in this wire, if any, by the deviations of the needle of the instrument. At the moment the battery current commences to flow through the first wire, the needle of the instrument is seen to deviate at first, then to quiver and oscillate, and finally to come back to an equilibrium,

which remains at zero, just as it was before the current was let on the first wire; and thus it remains undisturbed as long as the current of the battery continues to traverse the neighboring wire; but the instant the current is interrupted in the first wire, the needle suffers another deflection, and this in a contrary direction to that which occurred at the closure of the current. Thus he proved that the galvanic current which courses through the one wire, determines an instantaneous but opposite current in the other wire *at the moment when it begins to flow, and another equally instantaneous reverse current at the moment when it ceases.*

Dr. Faraday was led to suppose, from the manifest analogy existing between the properties of *magnets* and those of electro-dynamic *coils* or helices, that the same results would be obtained by introducing into the interior of the hollow helix a magnet instead of the electro-dynamic coil; and this he demonstrated to be so, and that even in a much stronger degree. In fact, the electric current that traverses one of the helices or coils of the machine at the moment when it is established, not only de-

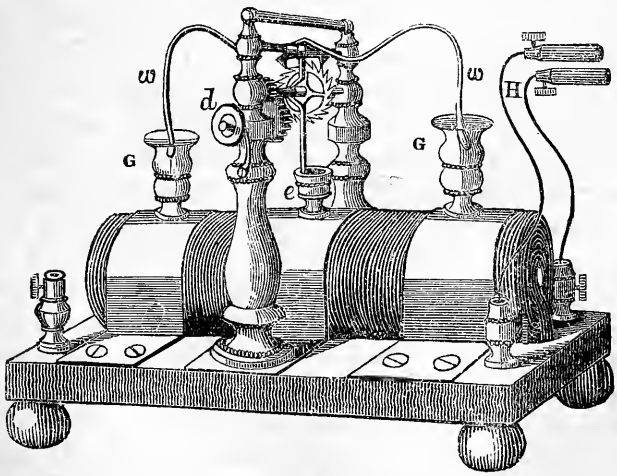


Fig. 49. An Electro-Magnetic Double Helix, with Clock-work for interrupting the Primary or Battery Current.

termines a current of electro-dynamic induction in the other coil of the helix, but at the same time, if there is placed a soft

iron within the helix, it magnetizes it; and for this same reason also determines in the second coil a magneto-electric current *in the same direction, and much more powerful.* So, when the current *ceases* to pass, the soft iron being instantly demagnetized, there is developed a second induced current *from the magnet*, which is now also added to that which results from the direct effect on the second wire in the helix — all proceeding from the inducing current that is flowing from the battery through the first wire in the helix.

The first physician who employed *induction currents* for medical purposes was Dr. Neef, of Frankfort-on-the-Main. He first *invented* the automatic vibrating spring for interrupting the current, which indeed opened a new *era* in the therapeutical uses of electricity.

Electro-magnetic currents, as they have been more generally called, are usually obtained from a helix machine, in connection with a single galvanic pair, (which latter is of itself a battery;) but, taken together, this is known in our country as the *Electro-magnetic Machine.* The *kind* of electricity thus obtained could

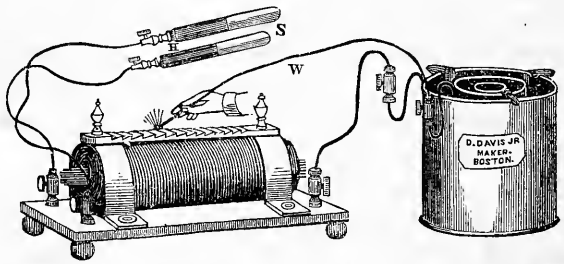


Fig. 50. Electro-magnetic Helix and Battery, with a Rasp for breaking the Current by hand.

be more strictly termed "galvano-magneto-electric currents of induction," because induced by both these sources combined, by the arrangement of one and the same apparatus. There are also other forms of induction currents that are called by other compound names. The author proposes, for the sake of conciseness and uniformity, to designate the peculiar kind of electricity obtained by any and all sorts of *induction* apparatus, whether from battery or permanent steel magnets, in connection

with *medical purposes*, as *Faradaic electricity*, *Faradaic currents*, and so on. True, the initiatory steps that led on to this grand discovery had already been taken by Oersted, Ampère, Arago, and by Henry; yet to the illustrious English philosopher, Dr. Faraday, are we indebted most of all for this magnificent result. Besides, it is well known that Dr. Duchenne, of France, one of the most distinguished medical electricians of the age, has already designated, in his elaborate work, the "localization of induction currents to a single muscle" as "*Faradization*." Let that kind of *current*, then, in this relation, and the medical use of these currents, henceforth take his name.

The term *Faradaic electricity*, wherever it may recur in this work, is simply synonymous with the terms "induction currents," "electro-magnetism," or "magneto-electricity," and stands in contradistinction to *Galvanic electricity*, for this latter term I confine strictly to primary battery currents.

The Electro-magnetic Machine gives us one of the most important forms of induction currents with which we have to do in all electro-therapeutics. Under this head, then, we must consider the construction and action of such apparatus, which are important, inasmuch as they have been, and still are, the more frequently resorted to for medical purposes. And withal, it seems but reasonable that a medical man should well understand the instrument with which he proposes to operate.

To be the better understood, we will set out with the primary law of physics, namely, that we can only derive force from some prior change of matter, which change ultimately resolves itself into some new form. If we find we have a certain amount of action in a *single* galvanic battery, it is given us as the effect of relative quantity. When the action takes place in a *series* of elements, i. e., in more than one pair, then, in proportion to the number used, do we get the relative effects of intensity. Moreover all the kinds of electro-magnetic machines yield us a current of peculiar *intensity*, although from a single galvanic pair whose simple characteristic is *quantity*. This excellent result is obtained by the power electricity possesses when passing through

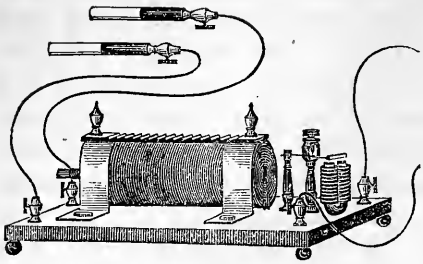


Fig. 51. Electro-magnetic Helix, with Vibrating Electrotome, but without its Battery.

a parallel and approximating wire, particularly when these wires are wound into coils of given lengths; and still more is the greatness of this result enhanced by the magnetic power that is also developed and exercised simultaneously in the same direction.

The coil or helix of all these machines, that are useful, is made pretty much *on the same principle*. A stout copper wire is well covered with cotton thread and varnish, for perfect insulation; and then some ten to fifteen yards of this is first wound into a coil, (which forms the inside of the helix of every such machine,) so as to allow the two ends of this coarse wire coil, which is but a part of the helix, to connect with the galvanic battery. This is termed the *inducing wire*, and the current of the battery when passing through this inner and stouter wire is designated the *inducing current*. Indeed, this current does *induce* the additional power from *two sources* — the one from a bundle of soft iron wires or a piece of soft iron that is placed within the central cylindrical cavity in the helix, and the other power from the outer and second coil of the helix, that will soon be described. But to understand as we go. If, now, into the interior of this primary coil of wire there is inserted the piece of soft iron or the bundle of wires while the current flows through the coil, the wire or iron is magnetized by the power of the current that is only passing from the battery through the helix and back to the battery. This is proved by the visible effects on a common magnetic needle placed under the wire, but very close to it; or it is seen the better by a galvanometer, so arranged that the current passes through this instrument, when it is found to be very decidedly increased, because there is added to the primary current of the battery *the induced current from magnetic induction.*

To finish the helix as it is, or *should be*, there is wound on or over the bobbin of coarse *copper* wire, that we have just been experimenting with, a second coil of fine copper wire of good quality, that is also well covered with silk or cotton thread and varnish, for perfect insulation: of this there should be at least five hundred to fifteen hundred feet, closely laid in the same direction over the coarse inducing wire. When thus completed, the two ends of the coarse coil connect with the battery. The two ends of the outer fine coil lead to binding screws, with which the conductors and electrodes can be adjusted so as to lead to the patient. The inner coarse coil can be arranged so as to yield the *extra* (*one-way*) current.

It has already been shown that when contact is made with the battery, the current which passes through the inner primary coarse wire determines in the second or outer longer and finer wire an instantaneous current *at the moment* when it *begins* to circulate, and another equally instantaneous current *at the moment* when it *ceases* to pass. Now, here is the peculiarity of this current from *electric induction;* i. e., it is thus always instantaneous, and that at the instant the inducing current *starts*, and again when it *stops*. The same is true of the currents of *magnetic induction*. And, fortunately, the magnetic current *can* act not only instantaneously and simultaneously, but also in the same direction with the other bits of currents; for these latter are not produced whilst the soft iron remains a magnet, but rather only when it gains and loses its magnetism. The demagnetization of the soft iron within the helix machine, therefore, must have the same effect as breaking the current of the battery in the production of an equally instantaneous current. It is clearly understood, then, that the current of the battery which circulates in the coarse wire of the helix never arrives at the patient.* It is only the *induced* currents (from the two sources, namely, from the within magnetized soft iron, and the without long fine coil of the helix that is rendered electric *simultaneously* by the mutual action of the battery and the magnet) that are felt at the electrodes. The galvanometer indicates exactly, not only

* Except when the helix is made for yielding the *extra* (*one-way*) current.

the existence of such currents as being only and always instantaneous, but also their *direction;* for if we compare the direction of the different currents, we find that the induced current — i. e., the one in the fine long wire that leads to the electrodes on *making* the circuit — is *contrary* to that of the current of the battery; while the direction of the one on *breaking* the circuit is in the *same* direction with that of the battery. We therefore find the *law, that these kinds of currents are but shocks, of only instantaneous duration, and that the direction of each alternate shock or current is invariably and necessarily in the contrary direction.*

To render such an arrangement available as a kind of *current*, there must be some contrivance for breaking and making the original or inducing current of the battery with the greatest possible rapidity and uniformity; and this is most beautifully accomplished in the best of these machines by the "*trembler*" of Dr. Neef. This is done by electro-magnetic power acting automatically on a magnet of soft iron, about which are made several coils of the large wire that forms the inner coil of the helix and connects with the battery. There is placed over the arms of this miniature magnet a silver spring that is faced and loaded like a hammer with a small bit of soft iron. This spring vibrates, with a mere hum from rapidity between the tips of the magnet and the end of an adjustable screw at its back, which is also tipped, but with a point of platinum; and this strikes against a pin-head button of platinum attached to the silver spring. And here is the most delicate point in the whole apparatus. These platinum points *should be riveted* to their place, *but never soldered.* The solder will become decomposed by the electric spark that plays there, and after a while the machine appears to be uncertain, or even worthless, although perhaps a good machine in every other respect. The author must say he has seen not a few of such; and not only so, but he has often found the apparently good-sized helix stuffed with something, besides hundreds of feet of insulated *copper* wire!

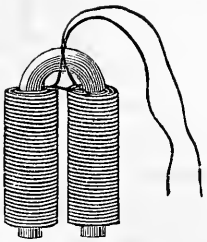


Fig. 52.
Electro-Magnet.

But to return. We have said that the original current of the battery is interrupted by the magnetic force of attraction and repulsion acting upon the silver spring, which is interposed so as to separate, and join the contact or continuity of the battery wire. The battery current renders the little soft iron a magnet, and this attracts the spring-hammer, and that demagnetizes the little magnet which allows the spring to fly back again; and thus is the current made and broken more rapidly and uniformly by electro-magnetic action than can be possibly done by any other mechanical arrangement. I should also mention, that the *face* of the iron on the spring should be kept clean and bright, as well

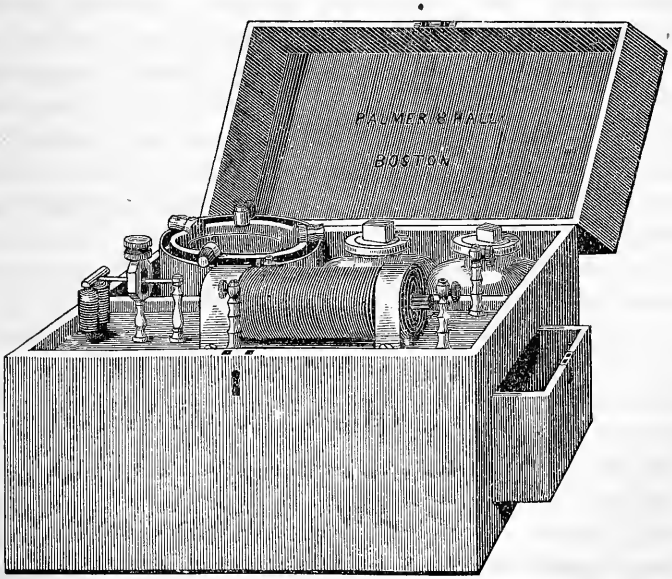


Fig. 53. Electro-Magnetic Portable Machine, complete in its Box.

as the ends of the arms of the little magnet, for either grease or rust will stop its action. The *contacts* must all be carefully attended to. Much power is often lost by this neglect, besides the inconvenience of uncertain action, or no action at all.

Go where we will, as I have said, we find a great variety of these electro-magnetic machines. Nevertheless, they possess in the main, generally, the same principle, and about the same internal arrangement or property for obtaining, in a greater or less degree, an *intermitting and alternating current of intensity*, simply from a single galvanic battery of great relative quantity. Some of these are good, others are not.

The intensity of these induction currents from a given machine depends, in the first place, upon the intensity of the battery action. If this is any way feeble, it will not develop a powerful magnetism; therefore the extra current from this source, as well as the current induced in the second or outer wire will be of low tension. The current can be made more heating and chemical by using a large and active battery with strong solution. Of course, it can be regulated or reversed in this respect, even to the lowest degree, by lifting the metal pair partly out of the fluid, or by diluting the fluid, or both. The intensity of the current, as regards tension, can be graduated to the greatest nicety by adjusting the soft iron or the bundle of wires that can be more or less pulled out of the end of the helix, which reduces the current, while pushing them in increases the current. So great is this range of difference that it is absolutely necessary to graduate the current in this way, invariably *before* applying the moist electrodes to the patient.

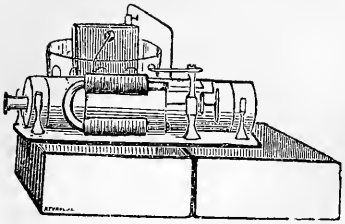
Another important point is to have the machine attached to the battery *invariably but one way;* and it is better to have the strongest pole always come to the right hand as we face the machine. We then can keep in view the whole, for this is the negative electrode, and the point where the current always leaves the patient. Of course, the other must be the positive pole, and where the current always enters the body or limb of the patient. By thus accustoming one's self to operate only in one way, it is more easy to keep the whole story of "current direction" clear, while the mind is more intent on the anatomical and physiological phenomena of the case. It is easy to determine which is the strongest, and hence negative electrode, by simply pressing the moist wash-leather or sponge of each electrode into the palm

of each hand, and particularly if so as to cover the inner edge of the adductors of the thumbs, which will respond by contraction most strongly to the negative electrode. The current should be strong, and the moist electrodes should be exchanged from hand to hand, back and forth, several times, until this is fairly demonstrated to our satisfaction.

A combined compound galvanic and faradaic battery (primary and secondary) *made portable*, expressly for medical uses, by Messieurs Legendre and Morin, of Paris, is a neat and most efficient arrangement. It is composed of thirty cups compactly set in a box for a compound primary current, as also a faradaic current battery. By the term *compound* we mean that whereas one cup is called a battery, so two or more, when attached together by wire from the carbon of one cup to the zinc of the next cup, are also called a battery; but it is compound, being made up of many cups or cells. This admirable battery is portable, and yet consists of thirty elements or cups, which are some five inches in circumference and four in depth, composed of *Delleuel's carbon*, which forms one pole, while the contained pole of zinc is amalgamated with quicksilver, and the charge is composed of forty-nine parts of water to one of nitric acid.

One of these cups is sufficient to put in action a most powerful induction coil for producing also a faradaic current. Two or more cups may thus be used. From three to thirty of these cups, when employed without the helix, yield a true primary current of so much quantity and intensity, for chemical action, that it rapidly reddens the skin, quickens the nerves and circulation, and warms the part, or the whole person.

The acid fumes from this battery cannot escape, as each cup is closely covered by hard gutta percha, and the whole is fitted into a secure and portable nest. The metallic connections, from cup to cup, are perforated so as to readily receive the wire tips of the conductors for the electrodes, which may thus be made to embrace any number of elements, without the need of a key-board, and measure the amount of current tolerably well without a galvanometer.



This figure shows *Smith's pocket electro-magnetic machine for medical purposes*. The box, containing the helix and conductors, measures only six inches long, three and a half wide, and two and a half high — any common-sized tumbler answering for a battery-cup. It yields a very powerfully intense *to-and-fro* induction current; also a powerful, hence very valuable, *one-way* current, (the *extra* current of Duchenne,) that is entirely distinct from the former current. Physiologically its effects are the same as an *interrupted* intense galvanic current. It is actively chemical and magnetic. Manufactured by S. B. Smith, 309 Broadway, New York, and costs eighteen or twenty dollars.

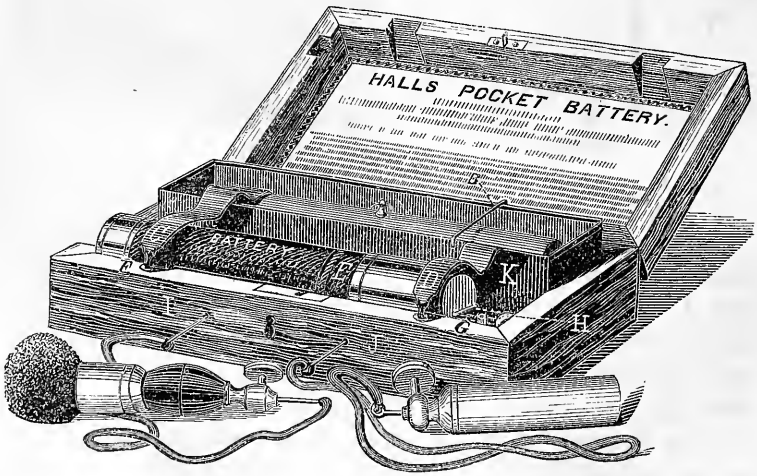


Fig. 54.

Fig. 54 represents a very powerful little faradaic battery of great simplicity, intended for medical use. Together with the spoon-sponge electrodes and conductors, it costs some ten dollars. It is so simple any one can work it; and it will continue in working order for years. Manufactured by T. Hall, Bromfield Street, Boston.

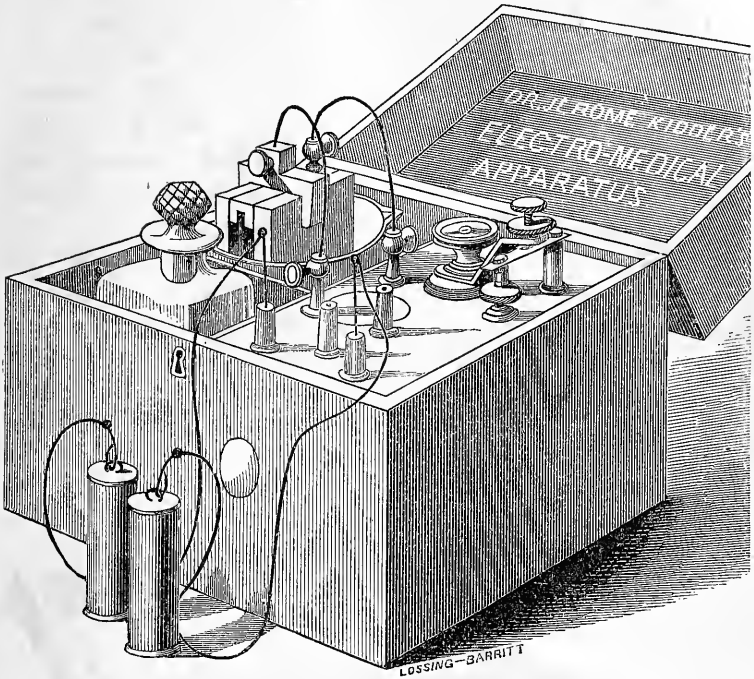


Fig. 55.

The Kidder Battery.— This is a modified electro-magnetic apparatus, manufactured by Jerome Kidder, of 483 Broadway, New York. It is a patented machine, and he has kindly sent me one of his new pattern, together with the specification of his letters patent. The *inducing* battery power of the Kidder machine is a Smee battery arrangement, as can be seen in the cut, such as is now frequently found in modern portable chemical apparatus. But his *tripod helix* has peculiarities that appear to me new and valuable; so we may say of his electro-magnet vibrator. Instead of depending only on the set-screw on the middle of the vibrator, he provides a movable clamp, and approximates or recedes the magnet also by means of an adjustable screw head in the end of the magnet, as may be seen in Fig. 55.

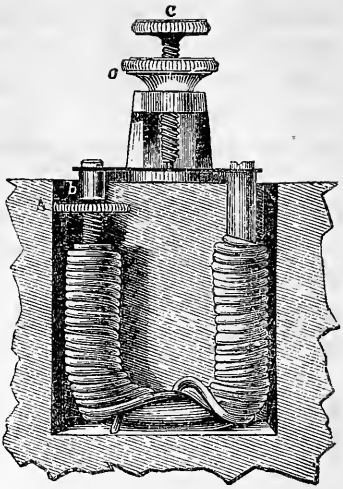


Fig. 56.

"The spring will vibrate well under a certain degree of battery power, when the hammer (b) of the spring is a definite distance from the magnet, which is usually one sixteenth of an inch. If the battery power be increased by stronger solution, or by adding more batteries, then the hammer is too near the magnet, and the spring will not vibrate well, but will give unequal interruptions, and will also make a jarring sound, unpleasant to nervous patients. He has obviated this difficulty by the screw with its head (A) in the end of the magnet, which can be *turned down* farther from the vibrating hammer when the battery power is strong, thus securing a perfectly smooth and noiseless vibration under all degrees of battery power.

"It is well understood that the current goes from the positive to the negative, and that two, and two only, of these posts are to be used for a current, as it is necessary to have a positive and negative in order to secure the same. When we have desired to represent simply electro-magnetic induction, without the galvanic current which electro-plates, we have used two arrows, one smaller than the other, and pointing in opposite directions; and we have called the current *alternating*, because it has been so called by various writers on electricity. But let it be distinctly understood that the use of this term does not express the exact quality of the current in this respect, especially as it works when the human body is a part of the closed circuit. It should, perhaps, be represented without the use of the smaller arrow, because the weaker current is so slight that it should not be considered, as under ordinary circumstances it cannot be perceived.

"The various currents of this *apparatus* are given out from

some two of the four posts lettered A, B, C, D. Each of these currents has different qualities. The right-hand post (A) to the centre post (D) will cause contractions of the muscles without much sensation: it is the combined power of the battery. From A to the rear post (B) is of low *tension*, and yields a strong *one-way* increased current (*extra*).

"Tension is not *power*, but a *quality* of current. If the current C and D (low tension) be made strong by *strong battery* power, it will act on the sentient nerves with cutting pain *near* where the electrodes are applied. Currents of high tension have greater conductibility, and will therefore traverse mediums where a current of low tension will not."

It is shown that each of the three coils of this helix is of different size wire, and different length, and so arranged as to be employed separately or together.

The following diagram, however, it seems to us, more clearly illustrates the sources of these modified currents:—

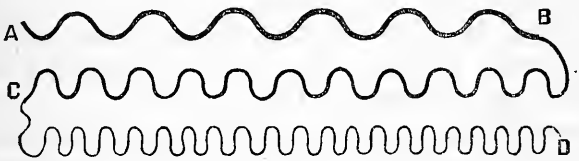


Fig. 57.

A to B represents the inducing large inner short coil, through which the primary current passes from the platinum plate in the Smee battery around to the amalgamated, quicksilvered zinc plate in the same, and thus *induces* currents in the outer coils. B to C is a much finer and longer wire, and represents the ordinary second coil of all helices; except that it is finer and longer, and of better material and better insulated, than is found in ordinary older faradaic machines. C to D represents the third or outer coil, which is of still finer wire, and yields a different power, if the conductors are at B and D; and when the battery power is adequate, it is of most powerful influence, *by intensity*, for conduction and penetration.

Hence, when the conductors that lead to the electrodes are inserted, on the top of the machine, as seen in Fig. 55, at A

and B, we get a small one-way current of galvanism together with a moderate current of faradaism combined, which is very highly esteemed by Dr. Duchenne, and termed by him the "*extra current*" of induction. It is often spoken of as a "direct" current. A and C affords the same, vastly modified by greater power of induction, and hence more intense; but adjustable by means of the withdrawing or insertion of the inner bundle of soft iron rods through the side of the containing box or case. B and C gives the usual induced current. A and D affords the whole combined power of this apparatus, provided the battery strength is proportionably increased. Thus we get a still greater power of tension and conduction, capable of overcoming greater resistance, and of influencing a nerve-trunk or nerve-centre situated farther from the site of the electrodes, and for producing, *without* more sensation or pain, more reflex action.

B and C yields the ordinary faradaic current, and is probably the one that is most frequently required; while B and D affords an extra strength of intensity — an advantage very frequently required.

Mr. Kidder has also kindly sent drawings and specifications of another patented machine, where he claims "two helices, or systems of helices, so combined and arranged that the induced current or currents of one may be added to the current or currents of the other; also, that the current or currents of one may be made to run in opposite direction to the current or currents of another, for the purpose of cutting off the power." This apparatus we have not seen, nor can we fully comprehend the utility of all the parts. But this, perhaps, may be inferred from his own explanation of the action of the helix of faradaic machines generally: —

"To produce a strong sensational current by means of a single galvanic battery, it is necessary that magnetism should be alternately produced and destroyed, in proximity with a coil or helix of insulated wire. If within the chamber of a cylindrical coil of insulated wire a permanent magnet of steel be suddenly introduced, a person holding the terminals of that wire will feel a shock caused by electricity then induced in the coil. If the permanent magnet of steel be suddenly withdrawn, another

shock is felt, as another current is also then induced in the coil. These two sensational currents, in *this case*, are in opposite directions, and are equal. Not so with the inductive influence excited by means of an electro-magnet, produced by a galvanic battery.

"Instead of introducing and withdrawing a permanent magnet of steel, if a soft iron core, or a bundle of wires within the chamber of the helix, be suddenly magnetized and demagnetized by means of the closing and interrupting of the primary current of the galvanic battery passing round it on an insulated coil of wire, the same result is also obtained as in the first-mentioned case, *with this exception:* the party holding the ends of the coil of fine wire will experience comparatively no sensational effect when the circuit of the battery is *closed*, but a strong sensation when it is broken. Though this fact is well known to those informed in regard to electrical phenomena, yet the cause of this discrepancy, we think, has not before been given; we will therefore call attention to it, as it appears susceptible of easy and positive demonstration.

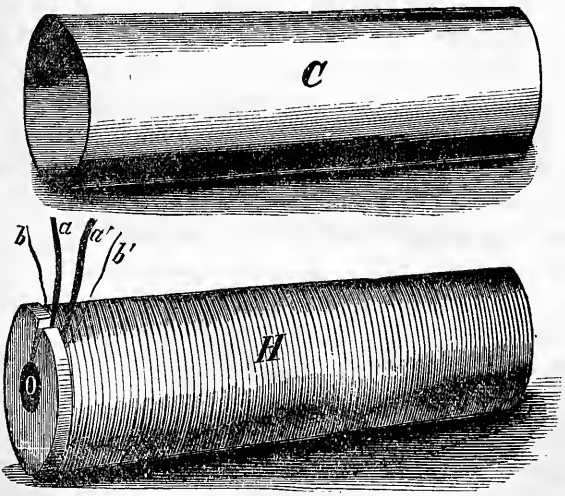


Fig. 58.

"In Fig. 58, *H* represents a cylinder consisting of two helices of insulated wire, the inner one having its terminals at *a*, *a'*,

and the outer at b, b'; O represents the opening of the chamber of the cylinder, which receives a core of soft iron that produces in the outer coil, b, b', a *sensational* current when the primary current from the battery passing through a, a', is broken, but *not* when the circuit of the primary current is closed, the reason of which will be perceived. If the copper or brass tube C be placed over the helix H, the sensational current is found to be wanting also in the coil b, b', when the primary current is broken, because this tubular cylinder, C, receives within itself the inductive influence; it receives it because it is *closed* about the helix, and is a much more perfect conductor than the human hands: it thus cuts off the sensational current from the helix.

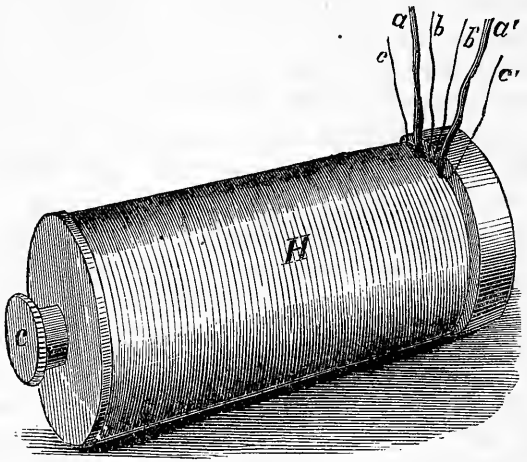


Fig. 59.

"In Fig. 59, the tube of brass or copper, C, enclosing the soft iron core *within* the helix, cuts off the currents the same as though it were over the helix. Also, if we withdraw the tube, C, and *close the ends*, c, c', of the outer coil, the same effect is produced: the induced current is received within that closed coil, so that the person holding the ends of another coil, b, b', would not receive the current; and *vice versa*, if the ends of the coil b, b', be brought together, then the current would be received in that coil, and the person holding the ends of the outer coil,

c, c', would not receive the current. Now, the operation of the machine *necessitates* the *closing and opening* of the coil a, a', for the primary current to magnetize and demagnetize the central core of wire. And when the coil a, a' is closed to produce the magnetism which would otherwise induce a current in the outer coils, *the very closing of that coil* with the battery causes it to *receive within itself the inductive influence that would otherwise be transmitted to the other coil or coils.*" Therefore, as regards the physiological effects, the current from the fine coil being truly *to-and-fro*, but strongest in one direction, acts more as a nerve and muscle stimulus; the current from the coarse coil is *one-way*, and hence is polarizing, chemical, alterative.

"The fact that the primary current is weaker at the first moment of closing the circuit — it not being instantly produced in its maximum strength — has been presented as a cause for the comparative absence of the sensational current on closing the primary circuit; but this is not, of itself, a sufficient explanation. The true cause is the closed coil itself acting in the manner as above explained.

"The interruptions of the primary circuit by means of the spring can be definitely controlled, so that the experimenter *may know when* the circuit is closed, *and when* it is opened, by taking hold of the spring, pressing it against the platinum point, and then removing it. And to experience the result at the same time, hold in the hands the handles or electrodes attached to the conducting cords receiving the current: the comparative strength of the sensational currents in opposite directions *may thus be known by experience;* and it will be found in accordance with the foregoing statements, viz., when the circuit is closed, comparatively a very slight, or almost no sensation at all, is felt; but on opening the circuit, a strong sensation is experienced.

"In closing the ends of the coil receiving an induced current caused by an electro-magnet, that magnet is stronger at the moment of the production of the induced current, and gives up its magnetism, resuming its unmagnetized state quicker on breaking the primary circuit when there is a secondary current produced by a closed secondary coil. Therefore, in running a machine, the vibrations of the spring will be stronger, or more

forcible when the ends of the inductive coil are closed. If this inductive coil, receiving the induced current, be constituted of long and fine wire, developing its corresponding quality of current, the greater change in the magnet will be observed or indicated by the still stronger vibration of the spring. To show this effect, nice adjustment of the hammer of the spring, so as in its vibrations to barely escape touching the end of the U-shaped magnet, is necessary; then close the ends of the coil of induction, and the hammer oscillates so as to strike against the magnet. This phenomenon may truly indicate the compound nature of electricity, and unfold more clearly the laws governing magnetic induction."

Thus we see that the sensational (induced) currents of electricity differ in regard to their concentrated and diffused action on muscular and nerve tissue, and also in regard to their action on the sentient and motor nerves. This difference in physiological effect results in a great degree from the difference in the conductibility or intensity of different currents.

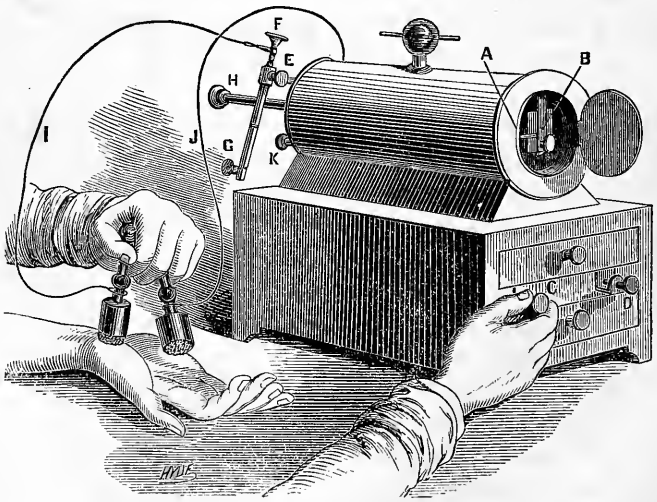


Fig. 60.

Fig. 60 illustrates the famous apparatus of Dr. Duchenne, of Boulogne, which yields two sorts of induced currents — the common faradaic current, and the *extra* current, which so much

resembles, in physiological effect, the true primary current; (it also gives a primary, sufficient for electro-puncture.) The galvanic, or *inducing*, part of this machine is very powerful; being, probably, more than five times as strong as the ordinary galvano-electric apparatus generally used in our country. The helix appears to be like those of other manufacture. Dr. Duchenne speaks of "producing sparks from the 'exciters,' along the surface of the dry skin," during his peculiar process of "*localized faradaization.*" The ordinary galvano-magnetic apparatus, such as we generally see, cannot produce this effect. This same figure illustrates his "*method of holding the exciters*" for performing localized faradaization on any part of the body or limbs.

Fig. 61 shows his "*exciters*," which are synonymous with what I term *electrodes*, and simply mean the terminals of the conductors, for applying electricity to the human body, whether they be moist sponges or metals.

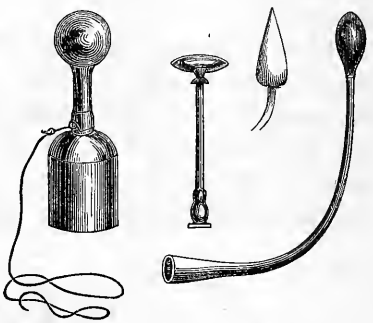


Fig. 61.

The two *connection wires that lead from the battery to the helix*, in every galvano-magneto-electric apparatus of any sort, should be large, or else composed of several strands of copper wire, sufficient to conduct, readily, *all the quantity* current that flows with so *little intensity* from a single or only double cell, as provided in these portable boxes. But, on the contrary, the *conductors* that lead from the apparatus to the electrodes, and so to the patient, should *not* be of large wire, because it is not sufficiently flexible to admit of certain delicate adjustments of the electrodes, so desirable, if not absolutely indispensable. These long conductors convey an *intense* current, and hence may be small. They are best when made of fine copper wire, twisted into *a metallic twine*, and covered with silk, or India-rubber tubing.

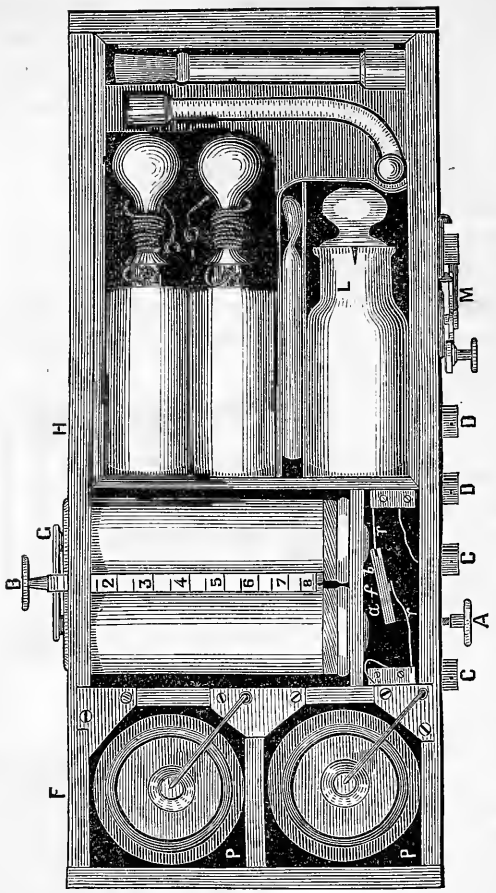


Fig. 62.

Fig. 62 represents that most portable and powerful little medico-electrical apparatus made by Ruhmkorff, in Paris. It is not so large as this book, and is not very liable to break or get out of order. The sockets C C yield the *extra*, or one-way current that so much resembles the primary. This current is very strong, but it can be regulated. D D affords the common faradaic current — and a most powerful current it is. G is a double helix of very fine copper wire, which is covered with a silvered shield that regulates the strength of the current. At P P there are

two carbon cups, in which we place about twenty or thirty grains of the bisulphate of mercury, from the bottle L. This is moistened with only one tea-spoonful of water, in each cup, and then the zincs, hanging by their side stems, fitted into metallic holes, are adjusted — when the whole is in operation to some purpose. The ratchet wheel at M is for suddenly interrupting the current. Thus it will run for an hour. Then the cups must be cleansed, and when put away, the accumulated quicksilver on the zincs must be shaken off, and the whole made dry for shutting up. The moist sponge electrodes, conductors, and other appliances should be placed in another box by themselves.

Fig. 63 represents Thomas Hall's celebrated portable medical apparatus. It is a faradaic arrangement, run by a Smee battery, most neatly and compactly encased in a small hard-wood box. It is clean, durable, and economical. It will run a week or two, or even a month, according to the amount of work it has to perform, without repairing or cleaning. But it is always best, and most economical, in using any Smee battery, to re-amalgamate the plates with quicksilver, and make a new solution (composed simply of twelve ounces of water and two of sulphuric acid)

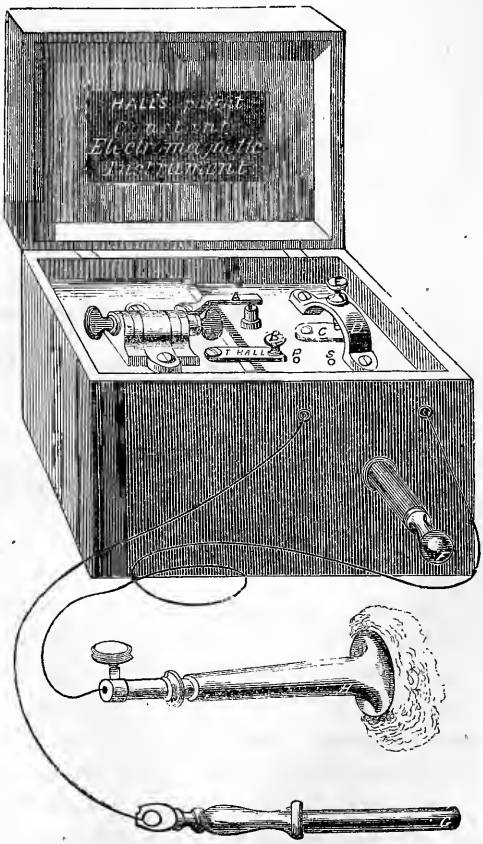


Fig. 63.

every week or two. This apparatus is also provided with *switches* and *covers*, which render it convenient and tidy; and as it affords two kinds of electric currents, — the common faradaic, as also the *extra* current, and sufficient primary for electro-puncture, — it is reckoned as one of our best American electro-medical batteries, especially for office use.

Directions for using it. — Raise the zincs out of the box, and fill the glass vessel to within one inch and a half of the top with water; add one ounce (or two table-spoonfuls) of common sulphuric acid, which should be bright and clear; then place the zincs in this solution, adjust the cover, connect the brass strap with the brass post opposite by crowding the pin into the hole, being sure that it makes good contact.

Move the lever, or switch, marked B, into the post opposite; this brings the battery in connection with the instrument, or helix, which will instantly vibrate the armature. It is necessary to give the armature an impulse with the finger if it does not start quickly of its own accord.

To stop the action, disconnect the battery by removing the switch from the post, as the zincs are only in action while the lever is on the post.

The battery part consists of plates of amalgamated zincs, and of platinum. The zincs must be covered with quicksilver, by being first immersed in a solution of about one tenth sulphuric acid and nine of water. This solution thoroughly cleans the zincs, so that the mercury can amalgamate with them. It is best to rub the mercury on well with a piece of cloth or a stiff tooth-brush. Care should be taken to avoid touching the platinum plate with the mercury; also, to keep the zinc plates well coated with quicksilver.

The platinum, or centre plate, must not touch the zincs, as this would stop the action of the battery. The electrodes are connected with the flexible rubber-covered conductors by screws, and the other ends of the conductors are to be passed through the eyelets of the box, and connected with the screws marked P and N, representing the positive and negative poles of the apparatus. By this arrangement the box can be shut, while operating, and so avoid the noise of the vibrator.

After running some time, if the current becomes too feeble, look at the zinc plates. If they appear blackish, they need re-amalgamating with mercury; but if they are bright, and coated with the mercury, the solution must be at fault. Never add acid to an old solution, but throw it away, and prepare new.

After having seen that the zincs are in good order, and that the solution of acid and water is clear and strong, if the instrument still refuses to operate, the fault must be in the vibrator. The armature must be adjusted so that the iron hammer, which must not be *rusty*, is about a sixteenth of an inch from the face of the magnet; then screw the spiral spring down so as to just touch the flat spring; then tighten the screw firmly by the lower nut until the battery works.

The strength of the current is regulated mostly by the brass tube being moved out or in through the eyelet-hole of the box. When this tube or rod is entirely out, there is no perceptible current; but as it is gradually inserted, it increases the current until it is entirely in, when the instrument will be at great strength. More acid in the solution will add still more strength to the current; and a certain fine and exact adjustment of the vibrator will greatly enhance the strength and evenness of the induced current.

The extra current, or the common faradaic current, as we may need, may either of them be readily brought to the electrodes by a switch on the deck of the instrument. When this switch is on the knob of brass marked S, we get the true faradaic current; when it is on the knob marked P, we get the less painful, but more chemical, "*extra current.*" The different currents are thus obtained, or changed, by merely moving the switch from one knob to another. This machine is very durable.

Hall's Petit Battery. — This is the most compact, portable, and powerful little battery of any description that is produced in this country. It is made by T. Hall, 15 Bromfield Street, Boston, and is for sale by all surgical instrument dealers in the country. It is the only faradaic apparatus here made, that yields only the *extra current.* It is most profoundly penetrating and chemical acting. It thus is capable of being a most efficient

aid in coldness and paralysis; for quickening the circulation, and thoroughly electrifying, and polarizing the nerves and muscles; for arousing from local palsy, or from suspended animation. Although so powerful, it is completely controllable.

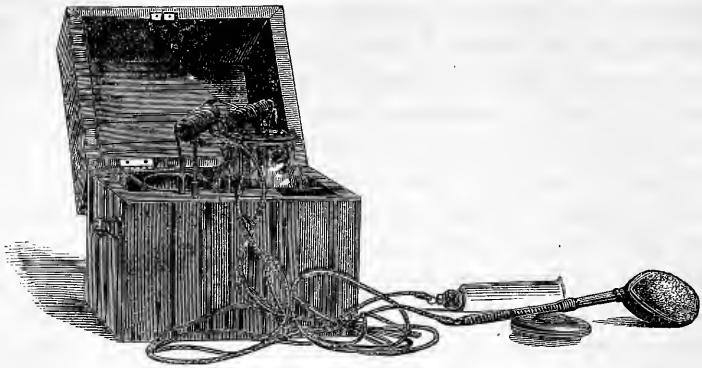


Fig. 64.

The strength of the *inducing* battery regulates the activity of this apparatus in a degree, and is much like the French battery made by Grenet. The pair is composed of carbon for the positive pole, and zinc amalgamated with quicksilver for the negative pole; while the charge is a solution of the bichromate of potassa in dilute sulphuric acid. The solution is made thus: First, take out the pair, and place it in the receptacle, which is a lead cup. Pour into the glass battery-cup about six ounces of water, (or two thirds full,) and to this add one ounce of clear sulphuric acid, (two to four table-spoonfuls,) and add two drachms of powdered bichromate, (a tea-spoon even full.) Now, this is a powerful charge, and entirely unsuitable for many cases; one half, or one quarter, the acid and bichromate, or less, is all that is required for the painful and more delicate cases. As soon as possible, after use, remove the pair, rinse it, and place it in the lead receptacle, and close the battery-cup water tight. It is thus safe to carry in the carriage, or to take in the hand to the bedside. When the solution becomes green, or blackish, it is to be thrown out. When a new solution is made, it should be cool before putting in the carbon and zinc amalgam pair. Thus it is always ready for use.

Medical electrical faradaic apparatus are thus variously provided with a galvanic or primary battery of more or less power and persistence. The helix, or coil of induction, also greatly varies in quality and power; but as an *inducing source* for faradaic machines, probably the Smee battery is the cleanest and most persistent; but Hall's "*Petit*" *battery* is unquestionably the most portable and most powerful, for this purpose, of any made in this country. Apparatus fitted to run with a *Berzelius* battery, "of copper cup and zinc cylinder," the fluid of which being a solution of the sulphate of copper, commonly called blue vitriol, and now probably more extensively in use in our country than any other medical battery, answers very well, with the exception that it is very soon oxidized, and requires cleaning every time it is used; but the solution of blue vitriol can be allowed to remain in the copper cup from week to week as long as it is good.

For *aura*, or *shock*, therefore, we employ the friction glass plate, or cylinder machine, producing from the atmosphere static electricity.

For obtaining the *primary current* for chemical action, and for polarizing nerve-trunks, as from a compound galvanic arrangement, we use a Daniell's or Legendre's, or Smee's compound battery, or a Pulvermacher chain.

For producing *galvanic heat* for cautery, &c., we employ Grenet's one grand cell, or Grove's dozen cells, or Bunsen's half dozen cells, as a battery *for heat without intensity*.

For a *local alterative*, and chemical action of moderate degree, as for healing old ulcers, &c., we use the little Humboldt battery, as made by T. Hall, 15 Bromfield Street, Boston, and by other instrument makers.

Thus we see that for *inducing* the more common and intenser secondary current, or the extra current, as through the helix of some sort of faradaic apparatus, we may employ a Berzelius, or Ruhmkorff's, or Grenet's, Legendre's, Hall's "*Petit*" *battery*, or Kidder's, Smith's, or Neiff's chemico-electrical arrangement; or the multiple horse-shoe magneto-electrical machine, according to the particular end to be attained; and sometimes resorting to either, as it may be our only choice, in a moment of extremest necessity.

Magneto-Electricity.

Magneto-electricity is a term used to designate certain induction currents from other induction currents called *electro-magnetic*, — these latter being produced by the electro-magnetic machine, while the former are produced, on the contrary, by permanent magnets which are called magneto-electric machines. This, too, was the result of Dr. Faraday's profound researches. He found that if the poles of an ordinary horseshoe magnet be *approached* by one of the ends of a copper wire, that is thoroughly insulated and wound like a helix around a wooden spool, then the needle of the galvanometer which is in the circuit is immediately deflected, but that the needle soon comes again to rest. This, he observed, was repeated also when the end of the wire was *removed* from the pole of the magnet, and that in the opposite direction; and then again the needle soon came to rest. This indicated that an instantaneous current of a given direction is produced when the wire of the helix *approaches* the pole of the magnet, — and that this is repeated, but in the opposite direction, when the wire is *receding* from the magnet. For producing a succession of shocks, so as to make up a current, the magnet, or else the wire, must be regularly approached and withdrawn in quick succession. To bring this about in the most effective and practical manner, there is hung upon a shaft a soft iron *armature*, that is wound on both arms with a long coil of copper wire for induction, and this is set in revolving motion near the poles of a large and fixed permanent magnet by means of crank, wheels and gearing. This is kept in lively motion by some person turning the wheel, the which turns the armatures some eight times around to its once, and the armatures thus passing the poles of the magnet twice to every turn of it, makes some sixteen shocks to every turn of the crank. Every time the armature coils approach and pass the poles of the great compound permanent magnet, the soft iron armature is magnetized and demagnetized, and thus two momentary currents of electricity are educed, — the one at the instant of approaching

and magnetizing, the other at the instant of passing off and demagnetizing.

The magneto-electric machine is heavy according to its power; but it is in a box, compact, dry, and neat. Its inten-

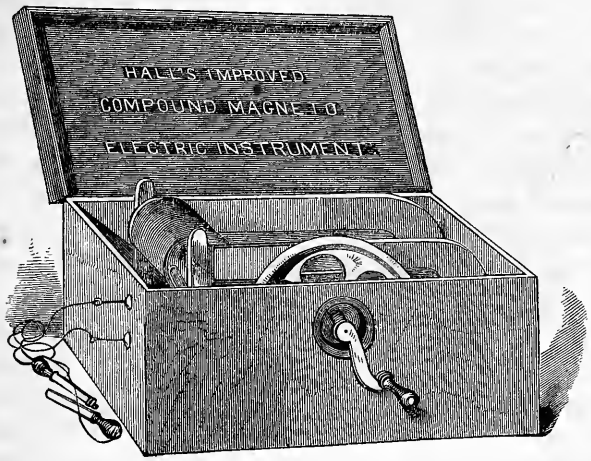


Fig. 65. Magneto-Electric Portable Machine complete in its Box.

sity depends, first, upon the power of the great magnet, whether single or compound; second, upon the size of the wire that is wound around the armature, and also upon the number of its convolutions; third, upon the exact nearness of the revolving armature to the tips of the poles or arms of the great magnet; fourth, and finally, upon the velocity and regularity with which the wheel is turned.

In this machine it is easy to arrange a spring cut-off on the large shaft of the armature so as to strike an alternate cog of brass and ivory, and thus to effectually intercept *one* set of the shocks that make up a one-way current, leaving the other to pass to the electrodes, as a current made up of fine shocks or bits of currents, but *all in one direction*. This can be demonstrated by showing decomposition of iodide of potassium or starch only at one pole. Thus we have not only an induction current with a nominal pole, but here are the positive and negative poles *truly so* in effect.

The most wonderful magneto-electric machine, of which we have heard, is the apparatus arranged by Mr. Henly, of England. In his machine there are arranged two banks of per-

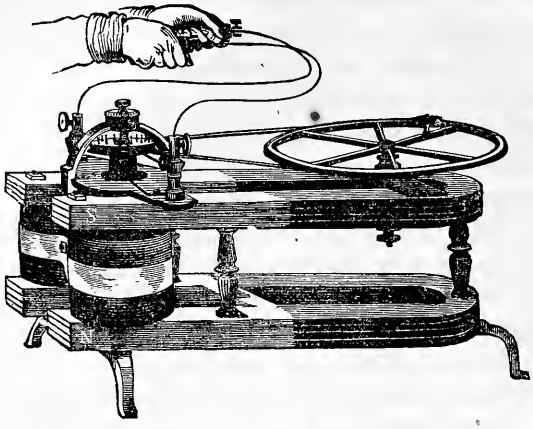


Fig. 66. Magneto-Electric Machine, showing its revolving Double Armature.

manent magnets, each of which is two feet and a half long, and five inches broad; each is made of extra steel, which was long and laboriously hammered. The induction coils on the two arms of the ponderous revolving soft iron armature contain some *six miles* of insulated copper wire, and all this is driven with great velocity and regularity by machinery and steam power. It is said that the electric power of this apparatus far exceeds that of Rhumkorff's coil; for the current obtained from the former is readily sufficient to kill a man or an ox instantly.

The physiological effects of magneto-electric currents are produced on making, as well as on breaking, the circuit; but the latter are stronger than the former, yet not to so great a degree as between the make and break in the battery circuit of the electro-magnetic currents. Therefore, when employing Faradaic currents for physiological and therapeutical purposes, we are allowed to take into the account merely the strongest current, i. e., those induced on opening the current of the battery in electro-magnetism, or on demagnetizing the armature in magneto-electricity.

Magneto-Electric Machines.—The *double* induction, discovered first by Professor Henry, of the Smithsonian Institution, which had never before been applied to magneto-electric apparatus, gives it a vastly increased power, when thus constructed, as they should be, with double coils on the revolving bobbin. The simultaneous intermissions of the magnetic current, and that of the central helix, produced by the rotary movement of the wheel, which puts in action the armature and the commutators, develop phenomena of induction in the wire of this central helix. Then, at the instant when the induction is produced in the central helix (first order) under the influence of the temporary magnetic current, if the conjunction of the two ends of the fine wire of the second coil (second order of current) make of it a closed conductor, there is developed in this latter a counter current, the direction of which is in an inverse relation to that of the first, coarser coil. There should be buttons leading conductors from both these coils respectively. The induced current from the inner, coarser coil is of moderate conduction. That from the outer, finer, and longer wire is far more intense, and capable of overcoming still greater resistance, and penetrating the deep parts more profoundly.

Finally, can we employ this magneto-electric machine and the galvano-magnetic battery indiscriminately, in all suitable cases, for electric treatment? No, by no means. The *magnets*, and other apparatus, may be thus used for cold, chronic rheumatism, callosities, and where there is a lifeless and insensible condition; for anæsthesia and paralysis without existing irritative lesion, and without a painful or excitable state of the nervous system; for cases of suspended animation, and for a rallying power generally, in all cases of haste; but it must never be long continued without more or less intermission.

We observe, then, that *Galvanic* currents differ from *Faradaic* currents in the following respects: —

First. The former are continuous and in one direction; the latter are always in interruptions, and these in rapid alternate directions; but as the terminal shock is stronger than the initial shock, so, when taken together, they make a stronger current in

that direction; and hence we call one positive, and the other negative; which, *in effect, holds true when acting on and through living tissue.*

Second. When the decomposition of water is brought about by the galvanic current, the hydrogen appears invariably at the negative and the oxygen at the positive pole. But if we decompose water by Faradaic currents, this is not the case, as each pole is *alternately* serving first for the positive and then for the negative pole, in rapid alternations, so that both hydrogen and oxygen appear at both poles. If these induction currents succeed each other very rapidly, it may even happen that both gases appear simultaneously at either pole, and, both being in a nascent state, they combine again so rapidly to form water, that the result is as if the water was apparently not at all decomposed by these induced currents.

Third. Another evidence that the Galvanic current and Faradaic current are not alike, is, by bringing a solution of the iodide of potassium and starch into the circuit of each; for then the blue color that indicates the liberation of iodine will shortly but moderately appear at *both* of the poles of Faradaic currents; while by the Galvanic current we notice the blue color quickly, and *only at the positive pole.*

Magnets as Remedy.

"*Loadstone*" and Magnets have for centuries been supposed to have some influence on the human body, particularly in disease; but it has always been in the absence of any tangible demonstration. Professor Faraday submitted his own body to the trial, by Dr. Keil, — who, at the time, was advocating those views, — with most powerful and formidable permanent magnets, but without any appreciable result. M. Pereira states, that as early as the days of Ætius, which was in A. D. 550, it is recorded that this then marvellous "*loadstone*" was bound upon the sick part. Dr. Alfred Smee has pursued a series of experiments for investigating this matter to some satisfactory result. He

placed the web of a frog's foot, and then the tail of a fish, under the field of the microscope, and there exposed them to the influence of very powerful magnets, but without producing the slightest effects upon the circulation of the blood, or upon the capillaries. He says he has also subjected the various organs of sensation to its influence, but never has been able to produce the slightest effect upon the eye, ear, nose, tongue, or skin. Nor was he more successful in his experiments on cell life, for all these trials gave negative results. From such trials, by one so competent, we may safely infer that terrestrial magnetism either has no kind of influence at all over the functions of *animal* life, or is so limited as to be usually an exception rather than a rule.

The "*horse-shoe*" magnet has also been resorted to as a remedy during the past century, and the result is, that both the natural and artificial magnets are claimed as peculiar and positive remedies for *gout*, *spasms*, *convulsions*, *epilepsy*, *tremors*, *cramps*, *neuralgĭa*, *rheumatism*, *palpitations*, *neuralgia of the heart*, *and true angina pectoris*. Persons affected with spasmodic diseases — epilepsy, catalepsy, chorea, paralysis, and hysteria — are said to be especially sensitive to this influence. It is on the nervous system that the magnet is claimed to exert its efficacy, and is applicable mainly to the nervous and spasmodic. While some it cures, a large proportion are not affected by it!

Method. — The chosen kind of magnet — of ten pounds, more or less, supporting power — is generally applied to or about the diseased part, and thus moved or maintained for a longer or shorter time, according to the case. From time to time it is drawn slowly along, close to the skin, over the course of the nerve that leads to the affected part. At other times, as for toothache, it is applied stationary against or near to the part. The celebrated Dr. Laënnec, who employed the *magnet remedy* in the treatment of lung diseases, according to the manner recommended by Hallé, i. e., by maintaining a magnetic current through the diseased parts, by means of several magnetized plates, affirmed that he "frequently found it to moderate the pain in pulmonary neuralgia, to diminish the oppression in

nervous asthma, to suspend spasmodic cough, and to control neuralgia of the heart." The author, however, has witnessed the application of true magnetism, by means of mineral magnets and by powerful steel magnets, for nervous diseases, in persons of highly impressible habits; but except in such, and apart from *the effects on the mind*, he is of the opinion that there is no physiological or remedial result; and these are the views of highest authority.

Æsthesiometer.

For the purpose of aiding in the diagnosis of certain forms of nervous diseases, Dr. Sievking constructed this little instrument, by whom it is at length described and recommended.* Its employment is based upon the principle, that the *capability of distinguishing the distance between two points*, applied exactly and simultaneously to the skin, at different parts of the body, varies with the tactile sensibility of the respective regions. This power, in health, always follows the general *laws of symmetry* that we find governing the body.

The absolute impairment of tactile sensibility may be ascertained by comparing a given result with the tables of Professor Weber, which are now contained in most new books on physiology. Thus, if a person in health is able to recognize, as two distinct impressions at the tips of his fingers, points of only one tenth of an inch apart, it follows, that if we find him *unable* on *one* or both hands to distinguish, say more than four tenths of an inch apart, then there must be a serious impairment of nervous susceptibility to the *reception* or *conduction* of tactile impressions.

The *nature* of the impediment must, of course, be determined by other evidences. But here it is manifest that, by applying an instrument to measure the exact tactile sensibility of different parts involved, or supposed to be involved, in a paralytic affection, we secure a more trustworthy standard, so far as it goes, to judge of the profoundness or extent and character of

* British and Foreign Medico-chirurgical Review, 1858, p. 280.

the affection than if we trust to the patient's description of sensations, or simply to the ruder mode of pricking or pinching the skin, as heretofore employed. There are three classes of circumstances in which the æsthesioscope, or "dividers," may be usefully employed as a help-diagnosticator: —

1. In suspected actual paralysis, to determine the amount and extent of anæsthesia.

2. As a means of diagnosis between actual paralysis of sensation, and mere "subjective anæsthesia," in which case we know the tactile powers are unaltered.

3. As a means of determining the progress of any given case while under electric treatment, or where waiting for treatment, whether for the better or not. Now, it would be superfluous to give illustrations of all these three classes of cases, showing where this might afford us some assistance. The first and the third speak for themselves, and to obviate any misunderstanding of the second, an instance is subjoined.

Case. M——, aged fifty-two, suffered, for six months before the first consultation, from numbness and *formication* about the left hand, with severe nocturnal pains along the tips of the fingers, and at their metacarpal ends. The patient rarely had pain in the thumb, and none in the palm of the hand. There was frequent vertigo. Now, to determine the character of this numbness, the æsthesioscope was tried, and the patient was found to be able to distinguish one tenth of an inch equally well at the tips of the middle and third fingers of both hands; i. e., of the sick hand as well as the well hand. The instrument therefore aided in the determination of the diagnosis, by showing that the *sensation* of numbness was purely subjective, but doubtless originating in the encephalon, as does *tinnitus aurium*, yet not the actual result of a true paralytic affection.

Fig. 67.

This instrument is essentially what is known to mechanics as a "beam compass." It consists of a square rod of brass, four inches in length, graduated and marked into inches and tenths of inches. At one end of this is a fixed point one inch long projecting at right angles, while another such point is arranged so as to slide along on the graduated beam, much like a shoemaker's measure. Certain precautions are necessary here in order to insure trustworthy results. And, first, *it is important* that the patient should not know what is expected; therefore he should not know *why* the instrument is applied; and the points should not be seen by him, so that the eye may not influence his answers to the tactile impressions. It is of all importance, moreover, to make the two points to touch the skin exactly at the same time, or there will thus be produced two successive impressions, which would alter the value of the result. We may use a pair of common dividers, or carpenter's compasses, in the same way and for the same end.

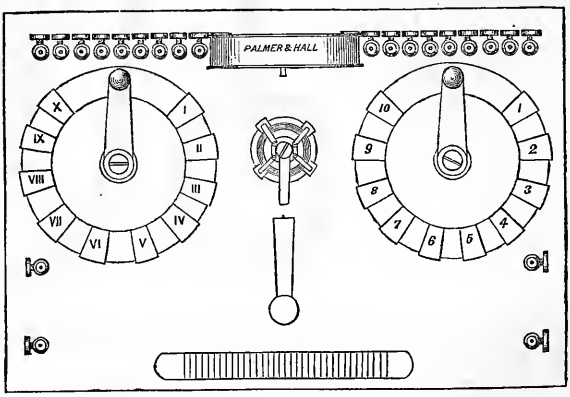


Fig. 68.

Key-Board, or Manipulator.—This is a very ingenious instrument, contrived for bringing any number of batteries into circuit at pleasure, from one to one hundred cups. It is arranged with a pole-changer, break-piece, and key. This is a very desirable instrument, when the constant current is used, as it places the battery in perfect control of the operator.

ELECTRODES OR POLES FOR MEDICAL PURPOSES.

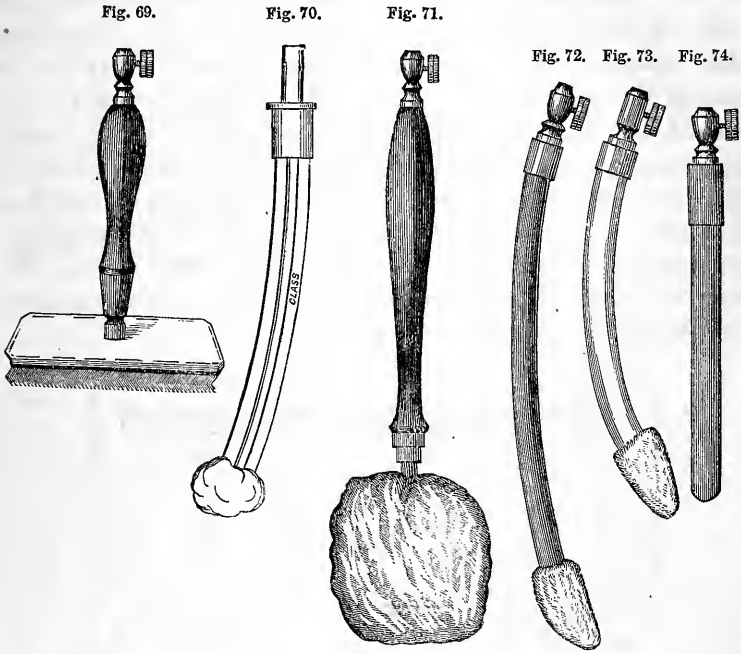


Fig. 69. Wire Brush Electrode for some local Faradization. See Fig. 88.
" 70. Sponge-tip Glass Electrode for Vagina.
" 71. Large and fine Sponge Electrode for general purposes.
" 72. Gutta-percha Flexible Electrode for Face, Mouth, and Fauces.
" 73. Gutta-percha and Sponge-tip Electrode for Uterus and Rectum.
" 74. Metallic Electrode, heavy silver plated, oval tip.

N. B. No electrode should be used the second time without having been perfectly cleansed. This is done for the sponges, in the first place, by warm water and soap; then rinse, and pass them through dilute *liquor sodæ chlorinatæ*, one ounce to a quart of warm water, allowing them to remain in it for a time; then rinse them again, when they will be perfectly sweet and bright, as if new.

Fig. 75. Electrode for the Ear, and other delicate purposes.
" 76. Electrode for Throat and Fauces.
" 77. Electrode of Silver, for the Tongue.
" 78. Handle Electrode, half insulated.
" 79. Handle Electrode, and Metallic Hollow for Sponge.
" 80. Glass Electrode for the Eye.
" 81. Ball Electrode covered with Wash-leather. There are *three sizes* of these, for placing over nerve-trunks.
" 82. Large fine Sponge Electrode with Glass Handle.
" 83. Duchenne's Exciters — Electrodes.

Fig. 84.

Fig. 85.

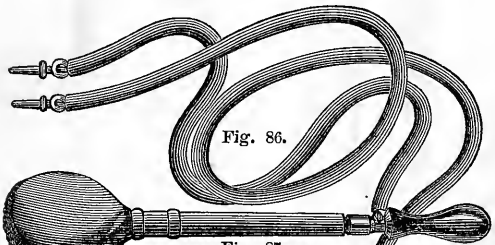


Fig. 86.

Fig. 87.

Fig. 88.

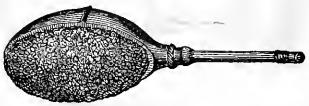


Fig. 89.

Fig. 84 is a view of my *Swivel Electrode*, for passing down inside of the dress of ladies, for the back, stomach, or bowels. The pad is metal, covered with buckskin, to be wet.

Fig. 85. — *The Egg and Stem Intra-Uterine Galvanizer*. The egg is made of fine silver, the stem is all of zinc, insulated one third of its length.

Fig. 86. — Improved Conductors, covered also with rubber tubing.

Fig. 87. — A view of my Electrode attached to the conductor, simply by means of the elastic tube, without binding screws.

Fig. 88. — The *Wire-Brush Electrode*, for *localized Faradaization*.

Fig. 89 (and 87) are views of *Garratt's Spoon Electrodes*, composed of a rubber, spoon-shaped insulator, lined with metal, and fitted with sponge; used for most general applications of electricity. Made by T. Hall, Boston.

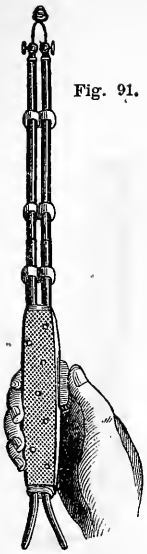


Fig. 91.

Fig. 90.

Fig. 92.

Fig. 93.

Fig. 94.

Fig. 96.

Fig. 95.

Fig. 90. — The *Handle Electrode* for holding either of the tips Figs. 91, 92, 93, 94, 95, 96, for galvano-cauterization. By moving the thumb-block the current is let on or shut off instantly.

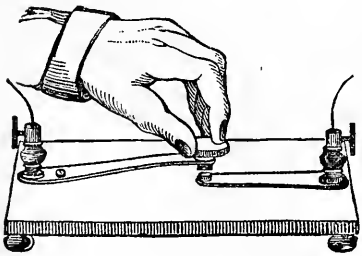


Fig. 97.

Fig. 98.

Fig. 97. — *Foot-Board*, or *Current-Breaker*, for dentists' use.
Fig. 98. — *Electrode Slipper.*

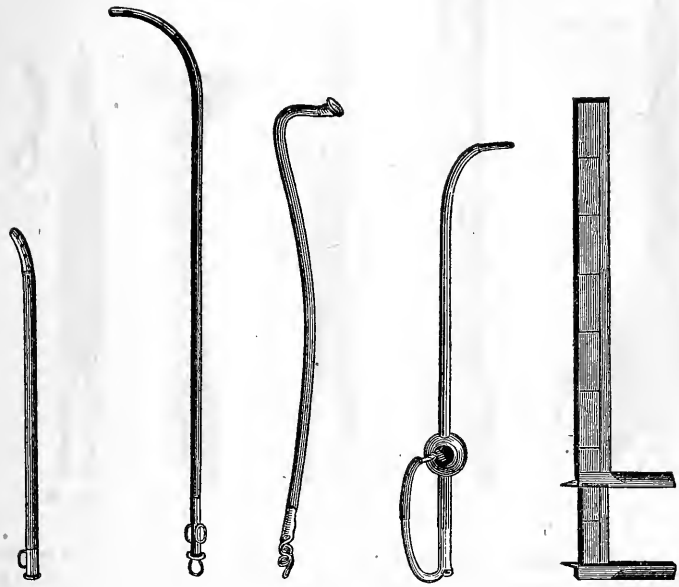


Fig. 99. Fig. 100. Fig. 101. Fig. 102. Fig. 103.

Fig. 99. — Insulated Female *Catheter Electrode.*

Fig. 100. — Insulated Male *Catheter Electrode.*

Fig. 101. — Insulated *Flexible Electrode*, with gold tip, for reaching the opening of the eustachian tube from beneath the palate.

Fig. 102. — Insulated Electrode, for electrifying the pharynx, glottis, or *chordæ vocales.* The end of the handle springs into a socket, to make and break contact.

Fig. 103. — Æsthesiometer, to aid in the test of lost sensibility.

Fig. 104. Fig. 105. Fig. 106. Fig. 107. Fig. 108. Fig. 109.

Fig. 104 is a view of my ivory and sponge *Ear Electrode.*

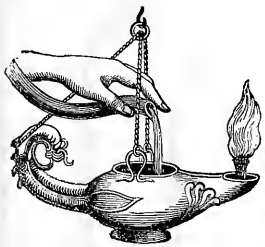
Fig. 105 is my Insulated Camel's-Hair *Flexible Ear Electrode.*

Fig. 106 is a delicate *Sponge-Tip Electrode,* for the eye.

Fig. 107 is also a very small sponge-tipped Insulated Electrode, for localizing accurately, as over a nerve-trunk, or for tracing small muscles. Figs. 108 and 109 are also for similar uses.

CHAPTER II.

METHODS AND RULES FOR THE MEDICAL AND SURGICAL EMPLOYMENT OF ELECTRICITY.



Alere flammam vitalem et morbo mederi.

Electricity as a Remedy.

In laying down precise methods and rules for the use of electricity as a medical and surgical agent, I shall, in this chapter, consider it only in relation to its physiological and therapeutical effects, and the conditions which are necessary to obtain a definite and reliable result. As these effects and results are materially modified by the *mode* in which the given electricity is developed, as well as by the *methods* of application, it will be inferred at once that a good and efficient apparatus, of a given class, that is also adapted to the given class of affections, is almost as important as the knowledge and skill of the operator.

The galvano-magneto-electric machines of the faradaic class, probably, meet the greater number of indications. In this class we might mention *Hall's Constant Smee Apparatus*, *Hall's* more powerful "*Petit*" *Battery*, *Kidder's*, or *Smith's Apparatus*, New York; *Apparatus of Neif*, Philadelphia; *Clark's*, London; *Ruhmkorff's*, *Dujardin's*, or *Grenet's*, all of Paris. But there are numerous other classes of cases that can be better, and more successfully, reached by static electricity, or by primary galva-

nism, as from a *Daniell's*, *Bunsen's*, or *Grove's* compound battery; or by that excellent primary and secondary one of *Legendre* and *Morin*, of Paris; or by the compact multiple single element of *Grenet*, for heat and cautery; or by the Pulvermacher chain, or the little *Humboldt battery*.

Precautions.

First of all, it is necessary to bear in mind that there is the greatest conceivable difference in individuals of the same age and sex as to their *susceptibility* to the effects of all electric currents; and these form *two classes* of patients. The first are those where there is *exalted sensibility*, and where only the most gentle procedure, and that with the most feeble currents, is at all admissible. In this class we may also include those with exquisite susceptibility to the *in-working* and also *reflex action* of the current, and that without their suffering, or even scarcely noticing it, during the *seance*.

The second class of persons are those where there is neither anæsthesia or paralysis, and yet there is a very marked indifference to the attempts of the currents. Some do not feel even the stronger currents; and others do not receive, or rather give no evidence of receiving, any impression from their in-working. For such reasons, great precaution is necessary in the employment of electric currents, particularly in giving the first *seance* for a new patient, until we study the temperament; even then we cannot always be quite sure that the patient will bear, or need, in the evening, what he took in the morning.

Accidents from the indiscriminate use of electric currents, or from carelessness in their use, or where absolutely injudiciously applied, as to the case, the length of time, the strength of the current, or the direction of the current, are real and serious. When it is not managed so as to produce good effects, it *may* be doing an evil work. Indeed, the very same current that is not only harmless, but beneficial, for one, to another of the same age and sex may prove so powerful as to be actually injurious, or so inadequate as to be quite inefficient. There may be produced, then, from too strong a dose of it, or too prolonged use

of it at a time, a bruising, or soreness, or fatigue, or exalted irritability, a neuralgia, or even cerebral congestion and hemorrhage. Now, some of the *slighter* of these effects are possible to be produced at the most prudent first *seances;* but in such a case the difficulty can be easily eradicated by treating it at the next time as an original and independent derangement.

The author fully believes that where electric currents are applied to the patient *without regard to the laws of their action on living tissues*, they may by chance produce, instead of amelioration or cure, an actual aggravation of the acute or chronic malady, which degree may remain (as he believes he has seen unmistakable examples) equally as persistent, as a correct use of the same currents will cause improvement, (by producing the opposite polarization of the nerve-fibrils and muscle-fibres,) or even a complete restoration, that is also persistent. These are no imaginary evils. Scarcely a week passes but some poor invalid sufferer presents for examination or treatment, who dates the "*growing worse*" from a given time, when "galvanized" by some ignorant person who applied the currents so shockingly, perseveringly, or repeatedly, that the hands were cramped, the muscles pained, and the limbs tetanized. *From that time* the paralysis was greater, or the pain along the course of the nerve trunks more acute, the aches in the joints more profound and unbearable, or the contraction of the limb more persistent. The would-be doctor may give bread pills for *placebo*, or dabble with ipecac, rhubarb, and saffron, but *never* with the contents of the surgeon's case, nor yet with the currents of electricity.

Before commencing the treatment of a new case, it is well first to ascertain as near as possible the extent of the pain or palsy, deficiency or deformity of the muscle or limb. I usually make a record, for example, of the angle of the tonic contraction — of the coldness or heat of the limb — of the height to which the patient can raise the hand or arm laterally, or in front, as well as behind the back — measure the *atrophied limb* very carefully, and ascertain the precise character of pain or remaining sensibility and muscular response to various stim-

uli. In the lower limbs, in case of sciatica, rheumatism, palsy, or spasmo-paralysis, it is important to find the angle the thigh can make on the body — how far apart the patient can separate his feet, or his knees, by his utmost effort, &c. Thus to scrutinize severely, *in the commencement* of each case, the minutest peculiarities, and the degree of these, for the correct application of galvanic or faradaic currents. Although unable to produce an improvement in some cases, yet in others not unfrequently the very first five minutes may obtain a partial and *permanent* improvement that would not otherwise be credited.

Especially must we always bear in mind the great difference there is in persons as to susceptibility to the influence of the *different* currents; and for that reason alone we should begin very gently, and make the first *seance* as short as the obtaining of some given end is had. Some persons, we find, can bear the most powerful and frequent applications of any form of currents without experiencing any after-workings; — while there are many others, who, after a single active trial, experience chills down the thighs, or drowsiness, or even lassitude. But others more frequently find from it a most refreshing sleep, where they had not had such before perhaps for months or years. Even an inability to sleep may appear in others after the first few sittings; but this usually gives way finally to most comfortable rest. By watching such after-workings we shall be able the better to regulate the frequency and activity of the *seance*. All these sensible by-workings and after-workings of the current appear only at and after the first applications, if the physician rightly graduates the strength of the current to the endurance of the case.

It is but a prejudice, and without any foundation whatever, to suppose that old people, little children, and extremely feeble persons, should not receive this kind of medication. Indeed, in my own judgment, these are the very persons to share in these blessings, only it must be adjusted to their endurance, kind of health, or derangement. Dr. Remak says it is his experience that the galvanic current is of the greatest value to aged and infirm persons, particularly for *prematurely old* men and women. He also

found it of very peculiar advantage to "*atrophic*" children. Probably this reference is simply to puny children, or to the marasmus, rickets, and scrofulous diseases of children.

The smart, prickling, or painful sensation of the current can, as a general thing, be a standard to guide us, or at least aid us to judge, as to how much the patient can or should bear. Yet we must bear in mind that there are cases, also, (as paralysis proceeding from the spinal marrow,) where the sensitive nerves are so utterly unexcitable that, although the entrance and leaving of the current causes the strongest contractions, the currents are not *felt* in the least. In such a case we must not proceed *trusting to this standard*, but refer to the number of elements, and to the galvanometer; or, if using induction currents, we must regulate the soft iron within the helix, or the battery power.

Electro-medical Terms. — Heretofore there have been much confusion and radical misunderstanding among medical men from the careless or ignorant use of terms, which has greatly retarded the knowledge and employment of electricity as a remedy. When reporting cases, and when giving the results of experience, one physician will speak of "*electricity*" without describing its form, or mode of application. Another will call the agent "Galvanic" or "Voltaic," or merely incidentally mention that the patient was "*electrized*" or "*galvanized;*" or perhaps only mention the apparatus; and one terms it "*electric*," another "*hydro-electric*," or "*volta-electric.*" Another, speaking of his success, or failure, will mention "*Galvanism*," or else "*Faradaism*," while his own account of the case, and the result of treatment, show conclusively that he was using exactly that form of the agent which he does *not* mention, and has *not used* that which he has mentioned. Here is a need of more knowledge, or more care and accuracy of expression.

A great variety of other ambiguous and compound expressions have been, and are, employed synonymously by medical men (many of whom, we have reason to believe, do know better) when reporting important cases of nervous or protracted maladies of the greatest interest, where cure, or relief, was brought about by some potent, hence *appropriate*, form and application of electricity of which deponent saith not.

From this cause nearly all that has been written on this subject as relating to practice, which would have been invaluable to the medical world, is lost; simply from the fact that we are not informed as to the exact *means* or *method* by which such favorable results were obtained. The consequence is, also, that very many medical men have vague ideas of a rational and scientific use of electricity, as a dexterous or skilful treatment, which should be accurately adjusted to the given case, as to quality, kind of strength, time, methods of manipulating the electrodes, kind of electrodes, current-direction, interruption, alternation, and the anatomy of the part involved in the affection that is to be treated.

In the gravest cases, sometimes, where faithfulness and skill are fairly baffled, electricity is thought of as a final resort and the only hope. Even here, too often, all that is precious in life, and that now lies in the trembling balance of suffering and safety, life and death, is submitted to any sort of an old or new, valuable or worthless, powerful or weak electric, magnetic, or chemical battery that may by chance be conveniently at hand, which is set to work "*applying electricity*" to the patient. Perhaps the case resembles one that had been reported, by some one, as "*cured by galvanism.*" Probably those ridiculous tin handles (electrodes) are placed respectively in the hands of the patient, so that the current runs up one arm, across the chest, and down the other arm; or one pole is placed stationary at the back or stomach, or is put into a tub of water together with the patient's feet, while the other pole is held in the hand of the patient; or it may be the doctor in this case "allows the current to pass through himself to vitalize the patient," — while the current, of whatever form, is all the while running, perchance, this way or that, — and this is considered, by many, as applying electricity! The patient is sometimes placed in a water bath, in a metallic tub, one pole in his hand and the other in the water, — this is termed an electro-chemical bath, — and so he sits, or lies, and takes the empirical dose of power, *haphazard*, for a half hour or so, no matter what be the disease. Of this, in the report of the case, it will be stated, "*electricity was tried.*" The result,

of course, is usually a failure; and though favorable in some rare cases, yet more frequently there is actual injury. Faith is lost. Resort to this agent, as aid in medical treatment, becomes rare; that is, it is resorted to only in desperate cases. How ridiculous all such bungling empiricism and quackery! What an abuse of means!

After all, it is my profound conviction, the result of many years of experience in the practice, that no one medicine or remedy in all the range of therapeutics can meet so many indications, and accomplish so much good, particularly in nervous, vascular, and chronic maladies, as does electricity, when proper cases only are subjected to it, and the applications are judiciously conducted. But, in a more just and truer sense, what an invaluable power it becomes, *as an aid*, in the hands of the intelligent and skilful practitioner, where it is made to be an intelligible co-worker with all other reliable remedies, coming years will surely testify.

General Propositions. — The first question that arises here is, where, and when, and for what practical indications, may electricity, as a therapeutic, be considered as indicated? By standard works on therapeutics, as Wood, Stillie, and others, we are justified in the following general propositions: —

1. To *stimulate* peculiarly and especially, by a given appropriate form of electricity, parts in which sensation, or the normal power of motion, may be defective or wanting; as in paralytic conditions of muscles or muscular power, or of general sensibility, or of the special senses.

2. To *correct* deranged sensations; which includes the quelling of pain and distress; to tone the cords and muscles, as well as to relax excessive contractions, as in some forms of neuralgia, rheumatism, &c.; to alter morbid nutrition by electrolysis and catalysis; to effect through its chemical agency a local coagulation of blood, as in aneurism and varicose veins; and to renovate simply exhausted nervous and vital forces, and to cauterize nerves and sanguineous growths.

3. To operate *revulsively* on the nerve-centres through the medium of the skin-nerves, as in various internal and profound

affections, even including some chronic inflammations, congestions, and organic plethora and rheumatisms; thus to promote digestion, or any of the secretions; or peristaltic action, absorption, and circulation; or to equalize animal temperature, as from the head to the feet; as also the nutritive and depurative processes, especially when electricity is directed to the flagging vital properties; also to awaken a keener susceptibility of the system to the action of other medicine.

4. To awaken the system generally, as in asphyxia, syncope, and from the poisonous effects of narcotics; and to recover from extreme exhaustion, and to arouse from suspended animation.

Methods for employing the various Electric Currents.

In the more recent German and Italian medical writings we find evidence that some leading men there are giving more special attention to this particular department of "*therapeutics*," than we find either in France, England, or America. Dr. Duchenne, however, was the first to partially recognize the great fact, *that there are certain spots along the surface of the body and limbs that give very peculiar response to the electrode in producing more ample muscle contractions without pain.* Simultaneously, and still more clearly, was this remarkable circumstance *discovered* by Dr. Robert Remak, of Prussia. He says, "After numerous trials on the different parts of living men, I am prepared to say that I believe I can explain those spots, or 'border points,' alluded to by Dr. Duchenne, as observed by him, but in only two muscles." In a very recent foreign work by Dr. Maurice Meyer, on "The Uses of Electricity in the Practice of Medicine," published in Germany, there appears the following description of his method: —

"*To produce electric excitement of the 'motory nerves,' or of the muscles, we must lay wet excitors with active induction currents on those points of the skin which lie as much as possible immediately over the said muscles.* We find that the surface muscles of the trunk, as well as those of the extremities, by operating in the manner thus prescribed, may easily be made to *contract;* while many of the deeper lying muscles may be

reached in the region of their *source*, or of their concourse,—*for there are such places*,—where they are peculiarly accessible to the direct in-working of the electric current. Where this is not the case, we must apply a more intense current, or have recourse to *Indirect Faradaization*, which, though probably less efficacious, either as effect or as remedy, is, however, here to be preferred." No mention whatever is made of placing the electrodes with reference to the oblique course of the fibres of the muscles, nor yet is there any allusion to the action obtained as being through the nerves, but direct excitement is plainly inferred. The fact of muscle *border points* has here too, doubtless, been observed; but its bearing for practice was not discovered.

I have elsewhere said — and it should be particularly borne in mind — that all persons are not in a like degree susceptible to the influence of the various electric currents. Not only does the application of the Faradaic currents show a surprising difference between one person and another, but I find that this can, and does, vary in the same individual from day to day; yes, even from morning to evening. This result of actual experience should have a place and bearing in the mind of every physician, as regards the widely varying susceptibility of different patients, and even of the same patient at different times, to the influence of a given dose of the various medicines, as well as to Faradaism or Galvanism.

There are cases, we know, where even the indiscriminate applications of small, wet electrodes to the surface of muscles, and with very moderate induction currents, such as are quite supportable by the sentient nerves, will sometimes produce a contraction of the whole muscle, or at least of the surface fibres of that muscle. This result is obtained most readily in proportion as the skin at that point is thin, and the muscle is also thin and lean, yet rich in nerve fibrils; as, for instance, on the muscle *trapezius*, or the *pectoralis major*. Here we can generally cause one or more bundles or layers to play at will, and this is the species of phenomena to which Dr. Duchenne refers, to prove the direct in-working of the Faradaic current through the muscle fibres, *independent* of the nerves; for he advocates the doctrine of Hallerian irritability.

Methods for using Static Electricity.

Friction electricity has long been, and *still is, valued for arousing and increasing the vital powers where simply sluggish.* The author has found it of very marked advantage for some invalids *who*, after great sickness or calamity, *remain in a low state of health*, and yet present no discoverable reason why they should not get better, only that there is a low tone of the nerves and functions, that cannot be reached by medicines or regimen. For these patients, young or old, the positive *electric air-bath*, taken sitting or reclining in an insulated easy-chair, with the feet upon the insulating stool, for half an hour a day, and occasionally alternated by sparks *drawn*, is a rational and often successful remedy. The machine requires to be turned very *steadily* and *quickly*, while the chain or rod director from the prime conductor is held in the patient's hands. At the same time, see that ample provision is made for the escape of the negative electricity — i. e., from the rubber end of the electrical machine to moist ground, or to some mass of *iron*, if near by. This can be done by a chain leading from it to the water or gas pipe. A dry brick wall, we must remember, will not always do this well. Now, as the patient becomes more highly charged positively, the hair will rise; and should the room happen to be dark, numerous sparks and luminous appearances will be observed, because the atmosphere about the patient is rendered negative, as it always is about a highly positive body. I have repeatedly heard the patients say, in the course of five or ten minutes after the *seance* begins, that they are warmer, and feel exhilarated. The circulation is found to be decidedly accelerated; and the secretions, especially the perspiration, become more active and general.

To give the *negative electric air-bath*, we have only to change the conductors so that now the prime conductor connects with the earth, while that of the rubber must lead to the patient. This negative electric state *is said* to be an electric antiphlogistic, acting by depriving or drawing off from the organism its morbid accumulation. But we cannot see the reason, nor

can we corroborate these deductions from any experience, as in our hands the testimony on this point has always resulted negatively.

Sparks may be *given to*, or *drawn from*, any part of the body, but they can be most readily obtained on a dry surface; for if the skin or the patient's clothing is moist, the discharge is thus dissipated, and we get no spark. *Electrization* by this means has been greatly esteemed by some experienced physicians for its success in curing chorea, hysteria, colds, rheumatisms, some forms of paralysis, and neuralgia.

While the patient is sitting in the *insulating chair*, and charged *positively*, sparks can be *drawn from* the body by applying any conductor near to the patient. If the person is being charged *negatively*, the same manœuvre will *give* sparks to the spot where it approximates. In either case there is a vivid flash of light, which, so far as it goes, is a streak of lightning. This is always attended with the sound of a sharp crack, as the negative electricity instantly combines with the positive. The sensation of a spark on the skin is like that of a slight prick of a pin; and this pricking sensation is in proportion to the *length* of the spark, as well as according to the *sensibility* of the part. Hence it is necessary to proceed gently with this by holding the ball of the conductor *against* the skin, or *very close to it*, at the commencement, until the patient gets a little accustomed to its sensation, when the discharger may be carried farther off to give longer and stronger sparks, and produce a greater effect. Giving sparks does not have so much effect locally as *drawing* the less frequent but longer sparks; for this latter produces a local accumulation of high-tension electricity in the skin and sub-adjacent tissues near the spot where the ball approaches the body. Here is the simple and most true localization of electricity. This method of applying electricity for the sick has been much employed for many years as the most efficient and reliable remedy for given cases, by Dr. Golding Bird, in the "Electrical Room" of Guy's Hospital. The *method* there adopted was as follows: A brass ball-tipped director, (discharger,) with an insulating handle, was furnished with an adjustable chain, or large wire

conductor, which is put in thorough connection with the ground. This, I find, is more readily done by using a good-sized chain, — say half inch, and silvered, — with a smooth hook on its end, to be readily adjusted on the metal shank of the discharger, and passing the ball of the discharger gradually and wavingly, more or less close, up and down the spine, within about an inch or so of the surface of the body or limb. It is understood that the patient is being retained positively charged all the while, by holding the chain to the machine, that keeps up the supply to the body, which here escapes to the ball and chain, and so to the earth. By holding the ball very near the skin, the sparks are so rapid as to form a mere interrupted one-way *current*.

Shocks from the Leyden jar are much employed in Europe for *amenorrhœa* by directing the discharge through the pelvis of the patient, from the sacrum to the pubis. When it is desirable to discharge the shock through any given part of the body or limbs, and that in a certain direction, we use a double discharger — i. e., one with a glass handle, and with two arms, that may be jointed and adjustable, or not, but the arms are tipped with bright brass knobs. One of these knobs we bring in contact with the point or region where we wish the charge to *enter* the body or limb. Then, if the outer coating of the charged jar has been already made to communicate by a good and ample conductor which is adjusted so as to lead to the point of the body or limb where we wish the charge to *leave* the body or limb, and we cause the second knob of the discharger now to approach the ball on the top of the Leyden jar which communicates with the inner coating of the jar, the jar is instantly discharged through the part of the patient so positioned. If the clothing and person of the patient are moist or wet from perspiration, it will require care and no little adroitness to succeed.

Dr. Cavello early published a small essay on "The Uses of Electricity in the Practice of Medicine." He strongly urged then the use of the machine in cases of paralysis, poor sight from want of nerve power, nervous deafness, chorea, epilepsy, and for restoring those who had fallen into the water, as he had succeeded best in all these with friction electricity. Dr. Cavello's

method was, to *draw the sparks through dry felt* or flannel. The patient sits insulated as usual, and takes the chain to the prime conductor of the machine in his hands; a piece of perfectly dry flannel is placed over the part which is to be electrified; and, the machine then being put in action, the brass ball or knob of the director that is in connection with the earth is then brought in close contact upon the flannel, while it is regularly and slowly moved along the part affected, and thus made to draw a succession of minute sparks through the cloth, as, for example, along each side of the spine, over the roots of the compound nerve trunks, as they take their exit from the cord. We may sum up the uniform local effects upon the skin and underlying tissues, as being in direct proportion to the efficiency of the machine, the length of the spark, the repetition of these sparks, as well as the delicacy and sensitiveness of the skin of the part operated upon.

The *electric shock*, it is well known, is given from the Leyden jar; one or more being employed, according to the power required. It is also known that in this arranged jar there can be *accumulated* a considerable quantity of electricity of the highest tension, and that on a comparatively small surface. The jar can be charged either positively or negatively. To charge it positively, the brass knob at the top of the jar is made to communicate with the prime conductor of the electric machine, while the outer coating communicates with the earth; then some thirty to fifty turns will charge a one-quart Leyden jar.

Methods for using the Primary Currents of Galvanism.

Rule.—When applying the *primary* current, or even the *extra*, or the faradaic current to any part of the body or limbs, for instance, and more particularly, when from ten, twenty, or fifty cups of Daniell's battery, *if it produces, or gives the patient, the impression or sensation of a coldness at the place where the electrodes are applied, or perhaps over a whole limb, which lasts for several minutes*, — provided this sensation is not the result of cold applied, as from cold water in the sponges, — then it may

be inferred that the nerves are extremely sick or feeble, near unto palsy; or, further, that there is actual disease at their roots in the great nerve-centres, and that this is *not* a suitable case to be so treated by primary galvanism. If *goose-flesh* is produced, we must come to the same conclusion.

But the foregoing test may often prove a capital diagnosis, which may guide us to the right future course and treatment. In such cases I always try again, by electrifying the skin and muscles smartly with a faradaic current; as it will not produce coldness in many of these same cases, but proves to be of the greatest service immediately; and indirectly, by quickening the system to a due susceptibility for the action of other medication. Thus there are cases where the repeated use of the faradaic current may be of the greatest service, even where the galvanic current, if it had been repeated or long applied, would have proved only injurious, if not quite disastrous.

Now and then we meet with an exception to the foregoing rule, viz., where the coldness is as fairly marked *at the first moments* of application of the electrodes, but which, in the course of a few seconds, *begins rapidly to change to a sensation of burning*. So that, in some such cases, if the coldness soon changes to heat or burning, we are not to give up the primary current, for it will aid the secondary in obtaining the cure.

A few remarks advanced by Dr. Duchenne some years since, in his great work on "Localized Electricity," respecting the inutility, and even "*danger*," of employing the primary galvanic current for medical purposes, have proved an effectual guard against its remedial use of late; so that almost no experience with the primary current has been obtained for the last ten years, excepting by a very few, whose testimony, however, is too high to be either overlooked or disposed of summarily. The first I will mention is that of Dr. Robert Remak, of Berlin, whose indefatigable labors and learned deductions command, at least, a respectful hearing. To understand this Prussian philosopher, we must observe that he is not a believer in the "*vis musculosa insita*."

According to Dr. Duchenne, "a *weak* and continuous current

of galvanism, when '*localized*' on the skin, will produce pains, erythema, and even blisters; while a stronger current will produce, when carried into the substance of a muscle, only feeble and irregular or uncertain contractions." This, at least, says Dr. Duchenne, "is the result of *an experiment* which I made on myself with a battery of one hundred and twenty Bunsen's elements. This constant current also produces the evidences of heat in the profundities of the organism, all of which phenomena are wanting if we use only fifteen to twenty elements." (!) In the fourth chapter he gives further proof by citing a case showing the workings of the steady current on the *retina*. It there appears that some kind of a new electrical apparatus was brought into his office by the inventor, while a patient was in the operating chair, suffering from a paralysis of the face. He thereupon made trial of this new machine, when, lo! the patient at once almost lost his sight. In the second case there also was brought in to him a new galvanic arrangement, (his own invention,) known as the "*Pile à rubans*," just as he was treating a patient for double-sightedness. When the doctor applied the current of this to the eyes of the patient, the latter jumped up, shook his head, and then exclaimed, "You have only *one* head! I no longer see double." This, in fact, is about all that we find from Dr. Duchenne on the physiological or therapeutical value of galvanism by a so-called constant primary current. True, he also mentions the fact that the constant current is less painful than the interrupted induction current, and as producing quick erythema, and even blisters. Speaking of the constant current apparatus which he employs for treating diseases of the retina, — *pile à rubans*, made of copper and zinc *ribbons*, moistened with the vinegar of wine, and hence extremely irregular in tension, — he says it (galvanism) is so uncertain in action, and so unmanageable, that it is quite unsuitable for other physiological or therapeutical purposes. Such are the amount and result of his experience, according to his own showing.

When treating of the physiological action of the primary current, Dr. Remak says, "I found from the multitude of my electric treatments, and especially from my experience with such patients as had been previously treated by some other surgeons

with the induction currents of magneto-electricity or electro-magnetism "*powerfully localized*" on the muscles, according to Dr. Duchenne's method, and particularly *in those cases of paralysis that arose from a central cause*, that although there were readily produced a plenty of tetanic or clonic convulsive movements in the affected muscles, by means of the *induced* (secondary) current, still they did not appear to restore the *voluntary* motive power; but, on the contrary, they sometimes evidently lessened this where it already had existed in some little degree, and that this *capability for voluntary action* appeared to be thus actually diminished by the strong induction currents, exactly in proportion as the given case of paralysis was depending at the time on a central source." (?) Subsequently, he treated alternate patients, in great numbers, by these two different kinds of electric currents; and the total results completely confirmed him in favor of the use of the primary current of galvanism, if used by a given rule, especially for those cases of paralysis, contractions, and fixed joints, *that depend upon an existing central lesion!* This, the greatest proposition of Dr. Remak, the author of this work cannot fully indorse; it savors too much of rash and unqualified statement, or of hazardous treatment; still, there is doubtless involved here a great physiological *principle*, that, we hold, should be watched and studied more and more, *as one of the very fundamental laws of both disease and cure;* viz., "reflex action."

Here I must also mention that we should take care not to ascribe the *absence* of sensation, absence of closing twitching, or absence of tonic contraction, to the *necessary want of action in the current;* and therefore it is of paramount importance for those employing the constant galvanic currents for therapeutic purposes to always include a galvanometer, or some kind of electrometer, as the galvanoscope, in the same circuit, so as to indicate *some*, but, better still, *the precise degree* of activity of the current.

As a general rule, I think the *comparative excitability* of *nerve trunks*, as uniformly shown by pain or contraction, appears greater the nearer the excited portion of the nerve lies to the brain. This holds good not only as regards single nerves, but it

is applicable to all the nerves of the human organism. Even with the motory nerves it appears to be a rule that here, also, the excitability decreases in proportion as it is made farther from the brain: thus tonic contractions can be produced on the human hand with so much the more facility the nearer the electrodes are placed to the brain over the trunk of the nerve *medianus* on the upper arm.

Wavy current workings are those that are produced by means of small metallic electrodes covered with wet wash-leather, flannel, or linen, and which are either hitched along over the surface, say every five seconds or so, on and in the course of the nerve, or held *more-and-less* firmly against the skin, so as to cause in either case frequent or constant changes in the density of the current. This method wakes up nerve-action.

Steady current workings are those used for down-toning — i. e., for purposes exactly opposite to excitations. For this purpose we must always choose *large*, soft, and moist electrodes, which must be gently and very gradually applied, and then held with an even pressure and moderate current, and then removed again, after the time, say from one to five minutes, with the same degree of precaution. This method calms the nerves.

There is a nice difference, also, to be observed between the *entrance* and *leaving* muscle contractions and the *closing* and *opening* contractions. These first, as we have seen, occur at the instant the current of the battery begins to course through the nerve and flesh; while the others occur at the instant the current is interrupted, opened, or broken, (as these latter terms are synonymously employed.) But the term "*entrance contraction*" refers to the putting on the electrode, *while* the current is still running, and the term "*leaving* contraction" refers to the removal of the electrode *while* the current is still running. On the other hand, the term "closing contraction" refers to the *closing* or making the circuit, as by the metallic switch contact of the key-board; and the "opening contraction" refers to the *opening* or breaking of the circuit by opening the same metallic key of the key-board. The latter division *is stronger in effect* than the former, probably because the electro-tonic state is more

readily induced by the very sudden change, than by the more gradual application and removal of the electrode. Therefore we obtain a rule in practice, that where we wish to *tone up*, or produce *increased excitability*, the quick, metallic making and breaking of the current is best. Also, for this, the choice of a brisk current through hard, moist, and moderate-sized electrodes is best. While, for *toning down*, the gentle putting on of the electrodes, and taking them away again after a *more lengthy* application, and this while the even current is still running, is always to be preferred; so, for this end, we should also choose the large, fine, and softest sponge electrodes, and employ the most gently managed, even, and moderate current.

We shall sometimes find that we can obtain, even from a medium *wavy working*, a moderate degree of down-toning in abnormally *exalted* nerves. But we must not be too confident that the *steady in-working* of the constant current through a nerve produces, by the induced electro-tonus, a diminishing of capability or of sensibility under all conditions and to any extent. Rather will we meet, in practice, with the more uniform facts that lead us to the belief that the reëstablishment or the increase of the somewhat existing *electro-tonus* in the nerve fibrils and muscle fibres, by means of steady currents, is the very best means for bringing the nerves into a condition most suitable for the normal or natural conduction of both peripheral and central impressions.

It is now ascertained, as I am inclined to believe, that the *current variations*, even when small, are sufficient to produce changes in the density and uniform direction of the native nerve current, and are more powerful and effectual to arouse an increased susceptibility in the nerve, for the future working of the applied current, than the *steady* in-working acting even for a longer time. Our experience also teaches that the increase of susceptibility in a nerve, appearing at a *wavy* in-working, is seen not only at the entrance and leaving of the same current, but even with a weaker current; so that, for instance, where a nerve is not susceptible to the action of a given primary current, — say from ten elements, — yet it will be made to acquire this aptitude

after a short in-working of forty, then thirty, then twenty elements, for a few seconds each, so that the nerve will now respond promptly to the ten. This increase of excitability, brought about by the current, is most easily traced, for example, on the muscle *biceps*, or on the facial muscles. We therefore lay it down as a *rule*, that a current which at first, as in cases of palsy, produces neither an entrance or leaving contraction, can be made to show it after having an in-working for thirty to sixty seconds of the same current strength, and this all the more prompt the longer the current has so worked. Indeed, very similar results as these last are obtained when, in the same manner, we use the *induction* secondary currents of *fine* vibrations as if a primary current.

From the repeated results at the electric *seance* of paralyzed patients, we find that the previous employment of say a half-quantity induction current, — that is sufficient to produce muscular contractions, although the electrolytic action of this, as shown in the galvanometer, being nearly at zero, — increases the susceptibility of the nerve and muscles for the after in-working of the constant primary current, certainly as far as that is shown by pain, redness, and twitchings at the entrance and leaving of the current. Furthermore, we find that the susceptibility of the muscles and nerves to the action of induction or Faradaic currents, and to constant or Galvanic currents, is about the same; but there are cases among healthy persons, and others still more marked among the paralytic, where the action of this current or that, decidedly prevails.

It is but a natural query, arising from many observations of Galvanic and Faradaic treatments, whether the change thus produced in the *electro-tonus* of the nerve and its depending muscles does not play an essential part in those cases where are shown the most wonderful and otherwise unaccountable curative effects of the various electric currents; although it is more in harmony with our present knowledge, and the prevailing opinions, to say that the *electrolytic* working of the current produces the restoration. I believe it is both.

"*Volta's Alternatives.*" — We look upon these manœuvres, in given cases, as some of the most powerful means we possess for

producing an in-working of the current in the fibrils of the nerves, and, in the ultimate muscle fibres, for *increase* of excitability. Yet, according to Dr. Remak, we must always make a rigid distinction between the *excitability* of a nerve or muscle and its *capability;* for these two terms are not, in these connections, the same.

I have never as yet been able to discover any diminution of susceptibility under the moderate use of this method of using a current, as to strength, say twenty Daniell's elements, or half power of induction currents; and as to time of each alternating, say, for an average, every fifteen to thirty seconds; and as to length of *seance*, say five or ten to fifteen minutes, — so far as it was shown by pain and prickle, by contractions, and other sensations. Not only so, but there is usually an *increased* response to the manœuvres of the electrodes; for where a motor nerve is embraced in the current that did not at first show any muscle twitch, it will, after a very few turns of the current-changer, respond by strong contractions in its depending muscles, or in their antagonists. This proves M. Marianini's observation to be correct, that "the *induced opening contraction* always indicates an increased preparation for the response to the production of the opposite current." We also find that this increase of susceptibility is augmented all the more, the more *suddenly* that change in the current is produced.

"*The Tetanus of Ritter*" — so often quoted, but, after all, seen only in the *dead* frog — I believe has never been observed in living men; i. e., after employing the constant current for remedial purposes: nor is any moderate working of a current able to render either a nerve or muscle not susceptible to the entrance of the same or the opposite current. But still I believe this might be produced by an unwarrantable and abusive use of a very powerful and painful current, repeatedly applied and reversed by a metallic current-changer, if persisted in for some time. So is a *guano* island desolate; and when guano is too powerfully applied to a field or orchard, it is well known that it kills; but in that very *power*, when rationally employed, consists its undeniable fertilizing capabilities.

Polar-working of either the primary or secondary current is a term given to whatever effects are produced *at the site* of the two electrodes, at the entrance, during the stay, and at the leaving of the current. This term, therefore, covers those older terms of "convulsion pole," "painful pole," and also those changes which were produced, or rather were supposed might be produced, by a protracted application of the electrode in the same spot.

Grapengeisser, Matteucci, and Remak, particularly, state that the action of the zinc pole of the constant or *primary* current, as of Daniell's battery, is the strongest. We find that the down-running of such a current produces stronger twitching at the closure of the circuit, during the closure, and at the moment of taking it away; while the up-running current produces more twitchings and longer enduring contractions, both at the making and breaking of the current. This *rule* applies not only to the superficial nerves at the borders and surface of the muscles, — as this can be distinctly seen by trials on the muscle biceps, — but it applies also to the deeper ramification of the motor nerves, even those situated deep inside the body of the muscle.

Intra-polar workings of electric currents are those which become apparent, even in healthy persons, in the territory of the ultimate ramifications of a nerve that is being embraced in the electric current; as, for example, where the current has been applied and maintained in the contrary direction to the natural nerve-current; and thus a modification in the latter is produced.

Extra-polar working of a current is simply that which is produced outside of the direct route between the two electrodes, and which is manifested by sensations or motions not properly arising through the nerve fibrils embraced by the current. These effects are more easily traced in sentient than in motory nerves. Under this head we will call attention to the fact that any one can observe, viz., that when employing strong induction currents, as upon the nerves and muscles of the arm, if the electrodes are pressed hard upon or over the motor nerve, *it lessens the pain*, and at the same time causes the contractions to take place stronger and deeper. This is a strange phenomenon. It

has been thought by some, that the constant primary current, and also the secondary current, does not act by a true *central* reflex action, but rather by the *painful* excitation of the peripheric nerves, such as are pairing off with their fellows of motory nerves, and thus causing contractions by a kind of *local* reflex action. But if this be so, how can we explain the fact just mentioned as to the Faradaic phenomenon? According to this view, when lightly applied electrodes with strong induction currents cover the region of a nerve, then there should be more contraction, because more pain. But we see that by pressing the electrodes deep into the flesh, the pain is *less*, while the contraction is so much the greater. It cannot be an exclusive action, then, of that sort.

We find that good electro-muscular contractions are not always to be produced either through the employment of Faradaic or Galvanic currents even on the nerve trunk, or on a pure motory nerve, until its branches in the muscles themselves have reacquired their excitability by the action of the current, i. e., by the *extra-polar* working of the current, which is possible even on the motory nerves; but this is realized, probably, only under certain conditions of the peripheric extension workings produced by the current.

Polar alternatives are those alternating motions in the managing of the electrodes during a *seance*, that is simply the removal or disturbance of one electrode while the other remains, and then the removal of the latter while the former remains, and so on, either alternately, double alternately, or treble alternately; i. e., three times lifting the one, and then the other three times, &c. By such manœuvres we are enabled, by means of one and the same galvanic, or even electro-magnetic current, to expose two different muscle groups, or nerve groups, in an *unequal* wavy excitement — a means of great value in a portion of cases that present for treatment. Those phenomena which appear in very excitable muscles, belong to the local workings of current variations in the nerves and muscles together, as where a current is directed through the motory nerve *peroneus*, which occasions, even at its leaving, a contraction in the depending muscles;

while a current of equal or greater strength, directed in precisely the same manner through the muscles themselves, shows no sign of contraction. If, now, we place one electrode on the muscle and the other electrode on the nerve trunk, then the lifting up of the *latter* electrode will produce contraction, while the lifting up of the other will leave the muscle still at rest; and this difference between the two will be the greater, the more care we take to produce waving or staggering of the current, just as the electrode is leaving the skin.

"*Alternations of Ritter*" may be understood by placing the two electrodes, say the one on the nerve *medianus*, and the other over the nerve *radialis*, in the neighborhood of the bend of the elbow where those nerves come nearest the skin, and then make contact from a battery of some thirty to fifty Daniell's elements, for there will appear, as a general thing, immediate contraction for flexion, which may also last while the current runs, producing a fair bending of the arm from the action of the flexors. Sometimes, however, this appears rather in the extensors. But if the direction of the same current is now reversed by means of the metallic key of the key-board, and that while the electrodes remain as they were upon the same spots, then the previous contraction, after a momentary recess occasioned by the turning of the current, appears again, (*and now with increased strength*,) or even will show it in the antagonizing muscle groups. Now, in case this latter result obtains, if the current direction be changed again very suddenly, as before, then the previous contraction comes in again, and this "alternation" appears so much the more readily in proportion to the suddenness and frequency of the changed directions of the current. Occasionally these results do not appear until after the changing has been repeated several times. Sometimes, moreover, these alternations of the current are attended with contraction of the flexors from the up-running current, while the down-running current produces contraction in the extensors; and this order of events follows the regular turnings of the current.

Wavy workings of primary, and also of secondary elec-

tro-magnetic currents, can be most easily produced by *changing the position* of one or both the electrodes up or down on the nerve course, or over the muscle fibres, so as to increase and diminish alternately the distance, and hence the amount of substance and resistance there is *between* the poles. This, I find, often proves actively remedial, even where it does not cause any visible contractions.

Wavy contractions are those which are produced in the muscles, or in the muscle nerves, simply by variations in the density of the electric current that passes through a given fibre, or group of fibres, or twig of nerve that ramifies the fibres, (but without actual interruption,) according to the *law* laid down by M. Dubois-Reymond, namely, that a muscle responds by contraction not only to the interruption of the current, but also to a variation of the current. These wavy contractions can, therefore, be produced when, from the effects of the current, the nerves and muscles have acquired a certain degree of excitability, and if we then give to one or both electrodes the least move, or by gliding them along a little without actually removing either of them from the skin, the muscle fibres over which the moving electrode approaches go into contraction, while those other fibres of the same muscle, or other muscles that the electrode leaves, at the same time cease to contract. If, now, the button-like electrode, that is covered with wet cloth or wash-leather, be moved along in a wavy or undulating manner *over the course of the nerve*, then all the muscle fibres depending on that nerve will be affected ; i. e., if they are in a state of sufficiently high excitability. Those fibres near by and immediately touched will also be influenced, but in a less degree. On the whole, the working will often *appear* to be the strongest in the muscle fibres themselves. We can produce analogous wavy excitement in the nerve trunk that occasions tonic contractions of varied degrees, according to the resistance the given current meets in its way. Wavy contractions can also be produced by directing one electrode so as to glide over the point of insertion of the tendon into the *farther end* of the fibres of the muscle.

We are led to notice that, for instance, in lean persons, when

the *platysma myoides* is caused to contract by Faradaic or Galvanic excitement, the skin of the neck is raised into sharp folds, over the contracted fibres of that muscle, from the *transversal* arrangement of the electrodes above the clavicle. Now, as soon as one of the electrodes is swept along, we get the wavy contractions in the successive fibres over which it passes. But the contractions are still stronger if the electrodes are situated so as to be according to the anatomy of that muscle; i. e., longitudinal with its fibres, if the electrode movements regard that mainly, although obliquely. In such muscles as are attached fleshily to the bones of the joints, the mechanical effect of the current is almost nothing when the electrode passes transversely across the fibres of them. But we can increase this effect, as, for instance, on the extensor muscles of the relaxed and down-hanging hand, *by a proper position or support, as of the forearm*, so that the current will then simply, from that little aid, produce a full lifting of the hand to a horizontal posture, while the electrode moves along rather obliquely across the direction of those extensor muscle fibres on the forearm, and thereby changing even the wavy contractions into a gradually increasing tonic together-drawing of the fibres of the extensor muscles, and thus producing a good stretch of the hand.

Sometimes we notice the wavy contractions of the contractile tissues and muscle fibres will appear *only* at the moving, and not at all at the stationary electrode. This is according to the excitability of the contractile fibres that come respectively under the electrodes. If the trial is reversed, i. e., if the previously moving electrode is now held at rest, while the other one is caused to vary and move a little, then, even, will the very same fibres twitch which are under or near the electrode that is at rest. This can be tested in another way on a large scale, as with whole muscles or nerve groups, if we place one electrode, for instance, on any point of the upper or forearm we choose, as on the nerve *medianus*, while the other electrode is made to move over the nerve *radialis*, or its motory branches in their muscles. The flexors will at first remain at rest, while only the extensors will get into a state of wavy movement; i. e., after a

time, when they have acquired a sufficient toning-up from the current stimulus, (which, however, sometimes fails to occur,) but which can be easily ascertained by a reverson of the trial. Even in cases of nerve and muscle sickness, and where the extensors are deprived of all voluntary capability, neither are able to be excited more by localized Faradaic currents directed to those muscles, still will their strong excitement, under the same conditions, bring about a contraction in the antagonizing flexor muscles, and this simply because the flexors were in that case already more susceptible to the influence than were the extensors.

Judging from all electro-therapeutic experience, we are led to conclude that the so-called constant or primary current of galvanism can place the nerves of a given case, even after an almost steady in-working on them, in a condition most favorable for the exertion of the voluntary influences of the will; or, in other words, to convey the natural messages of volition; and this, in plain words, means *to reëstablish the lost capability for normal action.* This constitutes *the cure.* Furthermore, we find that, for instance, in one portion of the cases of atrophy, the wasted muscles can certainly be plumped and rendered more firm and warm by the occasional practice in them of wavy contractions. But this increase in size is seen to be limited to those fibres or portions of the muscle which take on this response to the action of the current; from this it is quite apparent that the enlarging or growing of the muscle fibre groups is produced by an actual absorption of liquids along the sides of the muscle fibres, whose endosmotic capability has been thus increased by this current, or method of using it. The same can be done, but with more difficulty, by means of well-managed electro-magnetic currents.

By-workings of the current. — Under this head, and with all due deference to the views of Dr. Duchenne, we should first state our profound conviction that it is impossible to be quite sure of ever *limiting* the effects of any Galvanic or Faradaic currents to a single nerve or muscle only. Rather is it apparent in practice, that in every case a more or less simultaneous excitement of both the sentient or skin nerves, and of the motor or

muscle nerves, as well as of the neighboring contractile tissues also, is unavoidable; to say nothing of central reflex-action, which some of the most experienced and distinguished electro-physiologists and therapeutists also claim as a uniform result. The influence of the applied current, we find, will spread sometimes more, sometimes less on either side, as well as beyond, the straight line between the acting electrodes; and this seems to take place all the more through the adjacent and more moist tissues, the longer the current is kept in action at one spot. Where we are working a current over a nerve trunk, or the muscle, the only way almost that I have found to determine whether the stream is capable of gaining the proposed end, is to test whether the interruption of the current excites any contraction through the *motory* nerves. In many cases we find the evidence of good in-working through the *sensitive* nerves, by an eccentric sensation, which is a sign, whether *all the radiating fibrils* of the nerve are excited in an equal manner.

There are a very great number of by-workings of the primary current that are not so important. There is, however, an effect of this kind whenever an active current is applied about the head or neck, which causes flashes of light, dizziness, silver taste, or sound, besides a tendency to tilt the head over towards the removed electrode, for it is not during the steady working of the current that these results obtain, so much as at the putting on or taking off the electrodes. These effects are to be avoided, i. e., not to be often repeated with strength at once, as a mere experiment, but nevertheless are to be observed in practice as valuable *evidence of sufficiency of current for the given case*, and that the action of the current is certainly going on.

By-working of either primary or secondary currents on the heart is rarely produced; indeed, I can say that I have never as yet seen any kind of such effects, either in healthy or sick persons, from any of my ordinary rational applications, such as are required in treatments. But I would never risk the trial very powerfully, either for experiment or for treatment.

There are not unfrequently kinds of *after-workings* of this current in well persons, and in sick persons also, which should

be mentioned. In one case, perhaps, several hours after the *seance*, there will be sensations in the joints very similar to those produced at the time, by the in-working of the current; in another patient, there will be the silver taste often repeated; in another, there will be sensations like those from the vibrations of induced or secondary currents; in others, a prickling in a distant part or limb, which, perhaps, shows itself repeatedly; or there is a glow, or even a perspiration, where the skin has before been peculiar for its dryness. In other rare cases there are even automatic movements of particular muscles, or groups of muscles, that are repeated from time to time. Now, whenever any of these phenomena occur, we can rest assured that, whether the patient is benefited by our treatments or not, the needed degree of profound electro-nervous excitability is certainly not wanting.

Messieurs Becquerel, Dubois-Reymond, and Remak, are severally of the opinion that the properly managed primary constant current of galvanism can produce good and effective service in spasmodic diseases, not because of the paralyzing effects, nor from that tendency, but, says the latter, "because in certain cases *it restores to the central organs their power of dominion over the actions of the nerves and muscles*, the want of which produces or *allows* clonic spasms and cramps; in other cases, because it removes, by electrolytic in-workings, the peripheric or central irritation, where such is possible, through which many cases of spasmodic conditions are produced, and maintained, often, until the organism is self-destroyed."

In some eminently practical observations, Dr. Remak further says that, on account of the great variations in the excitement of the motory and sensitive nerves of patients paralyzed from *central*, or even local peripheric causes, it is absolutely necessary for the physician who proposes to apply the *primary* current of galvanism, as a remedy, to be first well equipped with every facility necessary to give him *a perfect command over the current* as to strength, the varying of its intensity, interruptions, reversing its direction, and as to electrodes of different sizes and material, as also the simultaneous and similar command of an ample induction or Faradaic current. He needs these, he says,

at least, to work up the sunken excitability of the nerves, so as to produce powerful contractions, and, at the same time, not to torment the sensitive nerves, nor yet to fatigue or exhaust the muscles. He mentions that he has found the current-changer of the key-board of great use in clearing away the tonic contractions of paralysis, and of old rheumatisms. He says such contractions are not relieved by an exclusive excitement of the once antagonizing muscles now paralyzed, nor of the muscle nerves. He then urges, in this connection, how little use is the mere local excitement of the muscles, and the nerve branches that are among the muscle fibres, in all those cases where the excitement of the larger nerve trunks is in effect, at least for the time, utterly lost. On the other hand, he shows the real curative effects of localized Faradaic treatments in those cases where the excitability of the large nerves is truly *diminished*, or even entirely gone as in lead palsies, for here we find the excitability of the branches in the muscles quite gone. Even in some cases of "progressive muscular atrophy" he found the excitability of the nerve trunks less than the ultimate twigs that were in the muscles, although then far wasted by the progressive palsy. He here recommends, therefore, first of all, and in every case, to ascertain and define, for one's own mind, the exact amount of excitability of the nerve trunk, and then proceed to the restoration, now in this, and then in the central direction, as we may find indicated, or to give the best results.

The degree and extent of the true electro-muscle excitement, according to the results of comparing trials, appear to be *in proportion to the sum of the motory nerve branches or fibrils that are embraced by the current* — i. e., that lie under, near to, and between, the electrodes. Dr. Remak interprets the weak or partial surface-workings of the electric current, from being applied along the course of the muscle fibres, as only the consequence of an excitement of the few superficial nerve twigs embraced, and which he terms "*extra-muscular action;*" while the deeper total muscle-workings of the current, which are produced when directed into the muscle by its largest nerve trunk, he terms "*intra-muscular action.*" Dr. Duchenne terms the former, as we

have shown, *immediate*, or "*direct, Faradaization;*" and the latter, *mediate*, or "*indirect*, Faradaization," for, as we have also said, Duchenne believes in the Hallerian irritability. Remak believes that nerves are absolutely essential to muscular contraction.

Without giving details, I will say that it has been fairly demonstrated that the blood vessels, including both the arteries and the veins, of the thigh of a living animal, as of a frog or rabbit, which has been subjected to the immediate action of a very "*strong* current of induction" for some ten minutes, do then actually dilate.

Drs. Duchenne and Remak have both of them Faradaized the diaphragm of man, the former operating through the *phrenic* nerve. The latter says, "The diaphragm seems to be a participator in the acts of respiration even more than any other of the thoracic muscles, and is susceptible to immediate electric excitements. I have produced by Faradaic currents, on some healthy young men, instantaneous, violent, and painless contractions of the diaphragm, which were indicated by the vaulting of the abdominal parietes on placing one electrode 'in the pit of the stomach,' while the other was on the most prominent curvature of the seventh and eighth ribs on the right side. It was interesting to observe the phenomenon while the currents were retained there, for, immediately after the current was applied, the tonic contraction (which was inferred from the arching of the abdomen) ceased, even while the current was still running. This was then gradually succeeded by a to-and-fro flapping of the parietes of the abdomen, and at the same time these persons expressed a conscious feeling of hickup. This clearly proved that the diaphragm was assuming its natural rythmatic contractions, even in the midst of the action of the electric currents, and while struggling with them. When the electrodes were removed, the diaphragm took on its normal functions."

The rule is then obtained, that in order to electrize the muscles truly, methodically, and at the same time beneficially, either by Faradaic or Galvanic currents, we must become familiar with the bifurcation of the nerves, which is synonymous with the

"*border points*" that simply mark the entrance places of the large nerves into the muscles. This knowledge is most readily obtained from experience in practice, and from trials on healthy persons; or on very recent subjects, as can be done only in hospitals or almshouses. Since the motor nerves almost invariably enter the muscle on its sides, we will, in doubtful cases, or if but little experienced, or in such as where the immediate affection of the nerve is, on the whole, not probable, act more judiciously by moving the metal *ball electrode*, covered with wet wash-leather, along the borders of the muscle, back and forth, until the spot is found and manifested by a good contraction, than by simply resting large sponge electrodes any where over the muscles, and regarding only the muscle fibres, according to the method of Dr. Duchenne.

The operator, although inexperienced in all this, will soon discover that he can produce a together-drawing, or contraction, of the muscle *biceps*, for instance, or of the muscle *deltoides*, or of the muscle *pectoralis major*, far easier by applying the one *small* and *wet* electrode to the spot of nerve entrance, and with the other so situated as to direct the electric stream lengthwise and somewhat obliquely across the muscle, than if he seeks to act only with reference to the long direction of the fibres of the muscle. I need hardly remark that in cases where the revival of paralyzed muscles is sought for, we then more especially must choose those points for the site or nucleus of wavy movements for one electrode, which, by trials on healthy persons or on the very recent subject, are shown to produce the most prompt and powerful effects. By this method, then, we succeed more surely, use less current, accomplish more in less time, and occasion less pain; and in the more doubtful cases of apoplectic paralysis, we also avoid any great degree of hazardous excitement of sensitive nerves, which will yet be more generally acknowledged to produce a uniformly greater or less degree of reflex action.

We have learned from Sir Charles Bell, as well as from our own trials, that the muscles do not distinguish between the sensation of heat and cold; and, besides, every surgeon is familiar with the fact how little pain the muscles experience when being

cut through; yet it may be possible to produce pain in muscles by means of the electric excitement. Dr. Duchenne observed that the electrization of raw muscle surface in a wounded fleshy patient produced only a dull kind of sensation, but no actual pain. I have already spoken of the manner in which large muscles can be brought into a painless, active contraction; and these form no exceptions, but are rather the daily experience in my practice.

Dr. Romburg, in his learned and excellent work on Nerves and their Diseases, distinguishes two great classes of conditions of the sensitive nerves of muscles — the one *hyperæsthetic*, the other *anæsthetic*. The normal shortening of the muscles during movements of the members takes place, it is true, without causing much, if any, sensation. But we learn further, from M. Weber's researches, what part the muscles take in the sense of *feeling* of tension, as when carrying burdens, as also in the pains we feel during cramps in the calf of the leg, during inflammations of the muscles, &c.* Now, this is a difficult question to solve, whether in all these cases the sensation experienced proceeds from the abnormal state of the muscle fibres themselves, or from their surroundings of sheathing tissues. According to the researches of Dr. Remak, the tendinous prolongations of the thin, flat muscles, as of the diaphragm, the *latissimus dorsi*, of the eye muscles, and others, present to ocular demonstration numerous nerves of medium size, composed of such fibres as led him to believe that they are none other than nerves of sensation. I have frequently demonstrated on healthy young men, who were my students, the possibility of managing the electrodes, even with a moderate current, so as to bring the *depressor anguli oris* to a tetanic contraction without causing the least feeling, as they themselves stated.

A man presented for treatment, or rather for advice as to the expediency of the electric treatment, whom I found to be afflicted with true apoplectic paralysis involving the *portio dura*. When testing the nerves and muscles of the face very gently,

* Ludwig's Physiology, vol. i. p. 360.

we found a small branch of the nerve *supra orbicularis* to run within a very trifling distance of the *border point* of the muscle *frontalis;* that is, from the entrance-spot of the motory nerve into that muscle. The two points are not half an inch apart; yet when one is touched by the electrode it occasions pain; when the other is touched there is a complete contraction of the whole muscle. The other muscles of the face are very similarly related, and for good reasons. It is thus that we discover, even on the smallest muscles, this pleasing result: that the currents of Galvanism, or of Faradaism, whose application insures the most powerful effects through the motory nerves — which are manifested by contractions — are also often the very ones that are productive of the least sensation or pain.

The operator, after all, cannot entirely avoid the sentient nerves. It would, therefore, be really desirable to have some means of uniformly avoiding or alleviating this annoyance and real drawback in electric treatments. Dr. Duchenne recommends the bringing of the two electrodes together before applying them to the skin. This is well to be remembered. We may (as is my own method) also apply the electrodes first, and then introduce the soft iron within the helix very gradually, while using Faradaic currents; or if Galvanic currents, begin with the switch on a low key, or no key, and then by running up the scale until the number of batteries is indicated by the produced prickling sensation, or by the galvanometer.

Methods for using the Faradaic Currents.

Electrifying the Nerves. — As regards the importance of a carefully, definitely directed transmission of the electric current — whether it be frictional, voltaic, galvanic, or faradaic — along the course of the nerve-trunks, *in a certain given direction*, especially in certain classes of cases, we must insist that we have very decided reasons — which are deduced from the study of the chapter on electro-physiology, and are confirmed by practice — for adopting, practising, and teaching it. For this reason, and to aid others to improve in practice, that chapter is intro-

duced. In fact, these are the very fundamental ideas that pervade this whole work. Not only the kind of current, and current *direction*, but also current *interruption*, *reversion*, and *duration*, we hold, are of the highest importance.

By placing the two electrodes over the course of a nerve, the positive being the farthest from the head, with a space of an inch or two, more or less, between them, of course there is an up-running current. It would be the same if the positive electrode was being moved over the depending muscle, or even if situated any where, provided it be below or beyond the site of the negative. When a current is so directed, it most keenly arouses the nerve towards its centre, and the centre also, and thus arouses the whole nervous system. Very many cases of nervous and chronic affections will not admit of this procedure; therefore, in these, it must be carefully avoided.

By the same disposition of the electrodes, if the poles are changed so that the positive is now where the negative was in the previous statement, we know there is now a down-running current, that is, from the centre outwards, towards the depending muscles. If such a directed current, moderate in strength, *be steadily run*, that is, without the least wavering or interruption, for five, ten, or fifteen minutes, it has a calming, soothing effect on most irritable and painful nerves and muscles.

By the same respective position of the electrodes, if now the current *is suddenly reversed*, as by the current-changer of the apparatus, or if even sudden interruptions be made, as by the foot-board, or by repeatedly touching the inner tip of the conductor to the button of the apparatus, there is produced a most thorough stimulating effect of the nerve and its depending muscles, as also at its centre. Then, if this procedure is combined either with a mainly up-running current or down-running current, we regulate the stimulating effect in any or all directions as we wish. But if the current is run only transversely, *across* a nerve or muscle, it has only a little and uncertain effect. These views we conceive to be fundamental.

Nevertheless, the large practical experience and learning of Dr. Duchenne, of Paris, lead him, it appears, to the following

somewhat different conclusions, which are condensed, but not altogether indorsed, by the author: —

1. "In man, whatever may be the direction of the currents, or the degree of vitality of the nerves they traverse, the same results are always produced when the conductors are applied to any portion over the course of the nerves — namely, muscular contractions and sensations.

2. "When a moderate or pretty strong current is prolonged for a considerable time, running along a healthy nerve, whether the current be continuous or interrupted, i. e., primary or secondary, if there are intermissions, it weakens neither the sensations, the contractions, nor the voluntary movements; nor produces any reflex phenomena above the point excited.

3. "Where an electric current is long protracted in its running through a nerve that is already considerably debilitated, it very notably lessens its excitability, but without influencing the voluntary motions in the depending muscles.

4. "Various changes in the current-direction produce no appreciable influence over the sensibility, or capability of voluntary muscular contractility, in man.

5. "Electrization of the terminal nerves, in a limb, produces sensations only in the points thus excited.

6. "An electric current which is caused to pass from the nervous terminals towards, or to, the nervous centres, acts principally on the sensibility of the limb, and produces above the point thus excited contractions which are irregular, and not in proportion to the degree of sensation."

Thus Dr. Duchenne regulates his treatments accordingly, in all, or nearly all, nervous affections, regardless of the relative positions of the electrodes, or the direction of the current, while operating; for his method being mainly *one*, — "*localized faradaization*," — the necessity for observing current-direction is somewhat obviated. He thus entirely ignores the fundamental laws of Dubois-Reymond, with a single exception, viz., "Should there be cerebral lesion existing at the time, the *inverse* current might do serious mischief." (Duchenne, p. 97.) He ignores the fact that headache and neuralgia may be produced by a strong

up-running current, even when there is no brain lesion. He ignores the fact that the sudden and repeatedly reversed current, while over the course of a nerve, is capable of working up tonus, muscle contractility, hyperæsthesia, and even irritability; and that the steady down-running current, coursing through a nerve-trunk, or nerve and muscle, or through the whole limb, produces, in certain other cases, a calming and permanently strengthening effect.

Such being the views of Dr. Duchenne, we can readily see why he so generally directs, in all cases, the grand electric remedy as a simple "*localized faradaization.*"

Localized faradaization is performed, first, by employing some kind of faradaic apparatus, either galvano-magneto-electric, or magneto-electric. Then, holding the two small brass-tipped electrodes in the same hand, so that they are but a very little separated, they are applied to the skin, dry or wet, according as we may wish to affect sentient or motor nerves, and thus holding them on, or moving them over, the part desired to be faradaized. For this purpose the *wire-brush* may be used as one pole, or electrode, it being most effective.

The effect of this kind of procedure is said to be "localized," that is, confined to the spot operated upon, or as limited to the skin. Second, the two electrodes may be covered, at their tips, with wash-leather or sponges moistened with water, and applied, as before, near together, over the moist skin, situated over the delinquent muscle. For faradaizing, the electrodes must never be more than from one to four or five inches apart, using a very smart or intense current, which produces little or much pain, that must be borne while this is being performed. We should aim to bring the whole of the muscle-fibres successively *in some oblique direction between the electrodes*, as also embracing the supplying nerve-branch, when possible, and so gently moving one electrode, or both, so as to electrify the whole. This, for some classes of cases, to be described in treatment, is most valuable. Hence I do not wish to be understood as disapproving of localized faradaization. I, on the contrary, for certain cases, greatly admire and practise it. But what I do object to, is the

subjecting of all cases suitable for electric treatment to this one method of application, and ignoring the existence, the approachableness and influence of nerve-trunks, and the polarity of the nerve-molecule.

To electrify the Organ of general Sensation — the Skin. — For this, conical *metallic* electrodes may be used, with full power of faradaic electricity, or thirty to fifty cups of galvanic electricity. If too painful, in the given case, use less current, else *dry the skin* by means of flesh powder or flour. Faradaic electricity is usually employed for this purpose, — using a high power of intensity, — as best adapted to allay local morbid hyperæsthesia, or pain, and for producing *revulsive* and *reflex* action. It may also be accomplished by drawing numerous short sparks *from* the skin, by the negative arm of a friction machine; as also by the succession of quick taps of electric heat from a button-faced metallic electrode, heated by a constant current of galvanism. This is my most valued revulsive and local alterative.

But, perhaps, the most powerful local nervous stimulant for the skin is the *wire-brush* electrode, attached to the negative pole of a highly intense faradaic current. To a healthy part of the skin, that is, physiologically, this performance can be rendered perfectly atrocious; but when there is anæsthesia, it is not readily felt. But it will arouse sensation and pain in any given part that is at the time possibly susceptible of it, or where it may possibly be ultimately induced. In all these cases the metallic brush, the ball, blunt or pointed metallic electrodes should be applied *near together;* or else one over a nerve-trunk while the other is on the affected part, and so moved, gliding along, over the surface of the skin, more or less, continuously, during the seance, usually so as to be not more than a few inches apart; or one may be planted stationary over the site of pain or palsy, (anæsthesia,) while the other is slowly or quickly glided about it. This I term *single circle movement.* When the two electrodes are moved thus back and forth about each other, in part circles, simultaneously, I designate it as the *double circle movement* of the electrodes. When they are applied to a given spot, and retained there, I speak of the application as *steady.*

To electrify the Muscles. — For this we proceed in one of these methods: either we must seek to operate entirely through the supplying nerve, by there applying both electrodes, with the positive nearest the head; or through the nerve and muscle together, by applying the positive electrode over the nerve-trunk, and the negative over the muscle; or else applying both electrodes directly on or over the muscles themselves, (by reflex action?) The skin should be moist, and wet sponge electrodes are best for this purpose. Where a deep and powerful effect is to be produced, as over a nerve, we often use the metallic ball electrodes, which work still better if covered with wash-leather and are well moistened with water. But my *spoon-shaped* sponge and rubber electrodes are the most convenient and the easiest to the patient, and are, therefore, most generally employed, especially when the patient suffers from a smarting or stinging effect on the skin.

When a healthy muscle, or group of muscles, is electrified according to my method, with a due galvanic or faradaic current, using my spoon-shaped electrodes, the muscle or muscles are seen to be brought into full play entirely without pain; but when performed by the method of Dr. Duchenne, the surface pain is decidedly sharp, and the muscle contractions are at the same time attended with a pain more or less considerable and peculiar, which is quite distinct from the surface or skin pain, and is referred to the belly of the muscle. I am enabled thus to accomplish the same work, *usually without* any sort of pain, that his method and apparatus perform *usually with considerable pain.* Not only is this my own judgment and experience, but it is the testimony of very intelligent patients, who, having received these treatments in Paris, by *faradaization*, for certain nervous affections, for the same affections had the same muscles electrified in Boston until a cure was confirmed.

First. I am careful to employ no more battery power, nor helix power, than just sufficient to produce the full and easy electro-muscular contractions in the given case.

Second. We use large, moist, fine sponge electrodes, spoon-shaped, of some one and a half by two inches in diameter, of

level and soft surface. The sponges in these electrodes — of which I keep some fifty pairs always in readiness, for I never use a sponge electrode on a second patient without cleansing it — are choice bits of the finest texture and smoothest surface sponges the market affords, and are to be kept scrupulously clean, and moistened in warm water.

Third. We seek to guide the positive electrode mostly over the nearest superficial nerve that supplies the muscle or muscle-group that is to be electrified; while at the same time the negative electrode is made to glide back and forth slowly and *obliquely* over the whole length and breadth of the given muscle surface; or else, or next, moving them simultaneously. We are sometimes to alternate them, if the case will permit, by single circle, double circle, or differential movements; or else to completely change their relative position, from time to time, say every ten or fifteen seconds, or half minute. Thus, by some or several of these manœuvres, we are enabled to thoroughly electrify deep-lying muscles, and even sick muscles with irritable nerves, with comparatively little disagreeable sensation; and also in such cases as cold, chronic rheumatism, paralysis, and simple nerve and muscle debility, not only without producing pain, but with a most agreeable sense of muscular motions that are sensible to, and appreciated by, these patients, who often express regret on having the *seance* close, and rejoice to have it repeated.

The electrodes are never to be allowed to rest long upon bony spots or tendons, with an active current, (excepting when purposely adjusted over joints,) for they are thus apt to produce pain, or a soreness, or an aching, that may be lasting; besides, it is doubtful if, in such places, where the current is so resisted, the electricity can do any good. Ignorant persons suppose, and have often been told, I learn, that there is disease in such places, because of this effect of the electrodes. Finally, for the smaller muscles, and for reaching more accurately the nerve-trunks, and for other more exact work, very small sponge-tipped electrodes, with a slim shank insulated, as may be seen on page 390,* should be chosen, and will give more excellent results. I consider a

* Compendium, p. 88.

suitable electrode, for a given operation, of very great importance.

But where there exists a painful or hyperæsthetic state of the nervous system, perhaps symptomatic of some diseased condition of the great nerve-centres, all these manœuvres by reversions of the electrodes, as also the up-running of the current, are totally interdicted. All such cases must be touched by the current only with the utmost caution and precision. In some cases the sensibility to pain is so readily produced or increased that this mode of stimulating the muscles cannot be repeated. Where such a state is suspected, we must only employ a very moderate current, and that always steadily, in a down-running direction, through large, moist, fine sponge electrodes.

Aside from hyperæsthesia and neuralgia, there are cases, perhaps from diseased or damaged nerves, where the muscles appear still to retain even some voluntary power, yet show no procurable electro-muscular contractility; while, at the same time, the electric sensibility is so great that no sort of current can be tolerated for a moment. Such cases, however, are rare exceptions to the general rule. Blisters are usually here first indicated, and then the electricity.

To electrify the Ear.—I do not approve of Dr. Duchenne's method of filling the ear with water, and then introducing into it the end of the wire conductor, as he directs. My method is first to moisten the meatus and tympanic membrane thoroughly with warm water, or soap suds, by means of a long camel's-hair brush; then to introduce the ivory ear electrode with a tiny sponge-tip moistened, until it is near to or against the drum of the ear. The operator should be seated behind the patient, the latter reclining in the operating chair, with his head steadied in the head-rest, or on a cushion. Adjust one large sponge electrode, positive, at the back of the neck, back of the ear, or over the opposite ear, or else the small electrode at the eustachian tube, according as the case may seem to require. Then take the wire end of the other conductor, negative, in the operator's hand, (using a very small current,) and so lightly touch the protruding wire of the already adjusted ear electrode with the

tip of the finger of the same hand that holds the conductor, so as not to injure the patient at first. Then, by degrees, the current can be gradually increased, or the finger moistened to make the contact more sure and complete. The ear electrode should be as deeply inserted as the patient well can bear.

Indeed, in my own practice, I can judge much of the sensibility of a given case simply by the introduction of the ear electrode, and thus, as it were, sounding the ear. Then, if quite insensible, I apply the wire of the conductor directly to the fine wire of the electrode, without the intervention of the hand; thus increasing or diminishing the current, or reversing it, as the case may seem to demand. We may proceed thus gently for five or ten minutes, and find that patients will bear faradaic or galvanic electricity, strong enough to accomplish all that is possible to be done, by this means. It must not be too painful; if it produces a noise, or a sensation on the tongue, or a metallic sour taste, it is quite strong enough. Thus used, in all proper cases, it is a perfectly safe treatment.

To electrify the Organ of Smell. — Any insulated shank, with a small metallic tip, or sponge tip, for an *electrode*, may be passed over the sniderian membrane with the primary or secondary electricity. If it is for loss of smell, or to rally from impending death, the faradaic current is best; as also in other cases, providing any considerable amount can be borne; if not, then resort to galvanism, with the positive large sponge electrode situated on the nose, under the chin, or at the pit of the stomach, and make smart, quick work of it, for what is to be done here should be done quickly.

To electrify the Organ of Taste. — An insulated stem, with a moderately small metallic end, or a sponge-tipped electrode, faradaic, and negative, may be passed over the surface and sides of the tongue and the palate, while the larger sponge electrode, positive, is placed at the back of the neck, under the chin, or at the pit of the stomach. If the current-direction is reversed, so as to run from the tongue, positive, to the back of the neck, negative, the effects on the great nerve-centre will be much greater; and if primary galvanism be employed, instead of the

faradaic current, then the central effect will be still very much greater.

To electrify the Organ of Sight. — For a muscular rheumatic, atonic, or a neuralgic or painful affection of the eyes, or *about* the eye, the faradaic current is almost always to be preferred. But for stimulating the optic nerve, friction electricity, as negative sparks, may be *drawn from* the eyeball through the closed eyelid; or primary galvanism may be passed from the positive sponge electrode at the *nuche* to the negative sponge electrode, that is being gently moved over the closed eye, and about it, as if bathing the eye with electricity; or one sponge electrode may be placed on each eye, and changed every few seconds. If flashes of light, or a metallic taste, is produced, the strength of current is quite sufficient. (See Rule 9.)

To electrify the Base of the Brain, the medulla oblongata, and the great nervous centre generally, we must apply an *up-running* current, directed towards the head, from along the spine; that is, apply the negative electrode at the base of the occiput, while the positive is planted at the coccyx; or is being moved slowly along up and down the back, or else held at some given point along the back, and every few seconds interrupted. Thus, by a current directed upwards, the medulla and brain are aroused and stimulated. By the same manœuvres with a *down-running* current, the great nerve-centres are also electrified, in a more moderate degree, but with a calming and down-toning effect, provided the current is moderate, steady in strength and direction, long continued, and not varied by being removed and re-applied at the same seance.

For effecting this most profoundly, the primary current, as from ten, twenty, or thirty Daniell's cups, is the most efficient. The next is the extra current, as produced by modern faradaic apparatus. If these are not at hand, the faradaic current, that is, the magneto-electric, or galvano-magneto-electric, may be employed. The application should be from one, three, five to fifteen minutes at a time, and repeated every other day, or twice a week.

While these are my regular methods, yet the same effect may

be produced by variations of this principle, for we cannot affect any one point of the brain without affecting the whole in some degree. Therefore, when desirable, as for a lady in dress, for instance, one electrode may be adjusted back of the ear, on one side, while the other is at the sternum, or on the shoulder, or just down the back a little. But be careful as to the current-direction.

To electrify the Throat. — For a rheumatic or debilitated state of the pharynx or larynx, and especially for palsy of the cordæ vocales, when not depending upon, nor complicated with, any organic disease, or lesion, nor symptomatic of other disease, electricity is the most valuable of all known remedies.

A small, slim, curved, *insulated* electrode, with a metallic tip, or sponge tip, is to be gently passed along down the pharynx, below the posterior part of the larynx, while the other, a larger sponge electrode, negative, is applied over the crico-thyroid muscle, on the outside of the throat. Then the current is to be let on, and the inner electrode is to be pressed forward against the larynx, and then moved gently up and down for a quarter of a minute or so at a time. Some throats will tolerate this procedure, but in others I have failed to succeed. Yet it is one of the most direct methods for electrifying the throat nerves and muscles, as for a weak or rough voice, or total loss of voice — *aphonia.*

The voice is sometimes restored, in certain patients, by simply faradaizing, *smartly*, the skin over the outside of the throat. This is also a most excellent procedure for the diminished strength, and roughness, of the voice, sometimes affecting those who speak or sing much in public, or in the open air; which may thus be relieved, and the voice restored.

To electrify the Vital Organs. — The heart, stomach, lungs, and liver are not only reached through reflex action, produced by the electrodes being placed on, or moved over, the given organ, but all these organs are *directly* acted on by primary or secondary electricity, through the pneumo-gastric nerve. By applying the pharyngeal electrode in the upper and lateral parts of the pharynx, and the sponge, positive, electrode to the nape

of the neck, all these viscera will be under the direct electric influence. But if we make the application to the lower portion of the œsophagus, which is done by a long, flexible, insulated electrode, with sponge or metallic tip, passed down the throat gently until near the cardiac orifice, then placing the other electrode, a large sponge, at the pit of the stomach, the electric influence will reach mainly the stomach and liver. The current should be moderate, and employed in short applications; or rather with frequent intermissions, between the applications, during the seance.

This is a delicate procedure, and requires care. If too strongly applied, it will produce faintness, and a sensation of suffocation. I usually finish each such seance by gliding the sponge electrodes as *hazing* (gliding them about each other lively) with smart faradaic currents over all the vital organs; that is, about the thorax, front and back, and around the waist. This often prevents spasm or cramp.

To electrify the Abdomen and its Contents, including the Uterus, the Ovaries, and the Bladder. For this we must employ some kind of apparatus that is active; for here, in most cases, is required considerable power. Large sponge electrodes are also best adapted for this purpose. One, positive, is to be adjusted first on the back of the neck, while the other is applied about the umbilicus. Then increase the power of the current gradually until the patient feels it very decidedly, or we see electro-muscle contractions. Thus we can bathe over the abdomen with a flood of electricity, as also over the region of the liver or duodenum, the colon, spleen, stomach, and diaphragm, the bladder, or the thorax, as absolutely as we formerly could with a liniment. This may be continued for five or ten minutes.

One, the negative, should next be placed at the umbilicus, while with the other electrode bathe about it very slowly, but smartly, over the whole abdomen, or over any given region of it, for another five minutes. Then *haze* the electrodes, or move them in double-circle motions. Now, if our object is to tone and contract the bladder, the positive electrode should next be applied at rest under the coccyx; but if for the relief of pains

in any of these parts, (excepting for ileus, constipation, stoppage, or flatus, with *atony*,) it should be adjusted rather down the thigh, at the inside of the knee joint, while with the positive bathe the abdomen, or the painful spot; or else arrange and adjust it in the rectum, vagina, or urethra, as the case may be. For obstinate constipation, for flatus, ileus, or intussusception from atony, the negative electrode must be carried well within the rectum. For more minute directions for electrifying the uterus, &c., see Rule 10, p. 466.*

To electrify the Male Genitals. — One electrode may be introduced into the rectum, while the other, negative, is passed down the urethra to the stricture, or the prostate gland, or *vesiculæ seminales*, as the case may be; or one electrode may be planted at the coccyx, while the other is guided over the perinæum, or through the urethra into the bladder. All but the metallic tip of the urethral electrode must be thoroughly insulated, for otherwise the sensation from the electricity, near the meatus, would be most horribly intense, while the current would scarcely reach the deeper parts at all. See the cuts of such instruments in chapter of apparatus and electrodes, and Rules 10, 11, and 12.

Where there is any lurking inflammation that is any way active, or any malignant disease in these parts, all forms of electricity are not only useless, but are contra-indicated; while for incontinence of urine from debility, impotency, *loss of power of erection*, or loss of power to eject the semen, or in atony and insensibility of these organs generally, the electric influence should be directed along the whole course of the urethra, by gently gliding the urethral electrode down and up the passage repeatedly, with all the current — primary, extra, or secondary — that can be tolerated for five or ten minutes. Then finish each seance by gliding the sponge electrode, negative, which has now replaced the urethral, over the lower bowels, and along the dorsum penis, over the perinæum, and about the loins and inner sides of the thighs, while the positive sponge electrode is all the while at the coccyx, or is arranged to be in the rectum. A very smart current needs to be employed for these sittings.

To electrify the Rectum. — For paralysis of the rectum, or

* Compendium, p. 164.

sphincter ani, for incontinence of the fæces, for rectal constipation, or atony of rectum, and for prolapsus of the fundament, where the sphincters are debilitated or paralyzed, the electrodes are to be directed to the sphincter muscles inside and out. The insulated metallic-tip rectal or vaginal electrode should be gently moved up and down the passage just within the anus from one to four or five inches, while the positive sponge electrode is planted at the coccyx, or is moved about over the perinæum, the electric current being as strong as the patient can bear. The rectum is, physiologically, but slightly sensitive to the current, to within about half an inch of the outside; but the skin surface of the anus, close about the passage, is, on the contrary, exceedingly sensitive to the current. This must be borne in mind, so that sometimes we shall find it convenient to make the inner electrode negative, and then carry the positive first to the coccyx, then to the lumbar region, and then over the lower abdomen, so avoiding that tender region about the anus in some of the more sensitive cases. For electrifying the uterus, see Chapter IX.

To cauterize the Rectum, by galvanic heat, as for hydatids, and other purposes, see chapter on Surgery.

Where the smaller branches of sentient nerves cannot always be avoided, and as the fine plush of skin nerves is every where present to greet the electrode, I usually employ a *strong pressure of the electrodes on the skin, to lessen the skin sensation* and pain; and this proves a most effectual means, as can be tested on the forearm or on the *interossei* muscles. Patients usually assure me that they do not feel any thing really disagreeable; and yet perhaps the muscles are in full play from the influence of the current. Others say that the sharp prickling or burning sensation produced by the too light or careless application of the moist ball electrode ceases as soon as it is more firmly held; and then in its stead there comes a dull, but more supportable, deep-seated, indescribable sensation. It is necessary at the same time not to make the pressure too great, for this will increase the pain rather than diminish it, not only from the pressure itself, but by conveying the current to the *periosteum* of some underlying bone. It is also important and necessary ever to give the

parts we wish to operate upon a firm and easy resting posture, such as will also make the *border point* of the muscles accessible, where it is possible to be done. Nor must we be too ready to remove or incessantly slide the electrode this way or that on the skin, unless it is to avoid a painful sentient nerve, or to move to, or more surely fix upon the exact spot we have been led to believe is the most suitable. The better way is to choose the spot, and then apply that electrode boldly and firmly at once, and hold it with a steady hand from second to second, or minute to minute, or less, but never more. These directions apply, however, more especially to the treatment of paralysis.

My advice is to commence with throwing aside the awkward yet every where provided and used metallic electrodes or "handles," as they are called. The custom has been to hold these in the hands, or to stuff wet sponges in their outer ends, and thus apply them to the body, or else drop one of them into a bath tub, together with the feet or hands. But all this is unphilosophical, hap-hazard, and, in plain words, sheer empiricism. It is better to make use of fixed insulating electrodes provided with metallic oval ends or surfaces, that vary both in form and size. Of these, some should be covered with large and very fine sponges; others with very small; while others should be covered with thick washleather; each must be thoroughly wet or moist (as well as scrupulously clean) when used. The moisture employed may be water or salt water. In my own practice I use pure water exclusively for the last moistening of the electrode sponge or leather.

I employ in anæsthetic and paralytic cases three sizes of metallic oval-shaped electrodes: the first is half an inch in diameter; the next is one inch; the next is two inches. For the *interossei* and other narrow places, I have others wedge-shaped, so that they can be easily crowded down between the phalanges; and these are very useful, also, where the nerve trunk lies deep, and we wish to bury the current-giver deep into the thick flesh. Such electrodes are preferable for cases of paralysis, and wherever there is nerve or muscle anæsthesia. But for almost all kinds of hyperæsthetic cases of nerve, joint, or muscle affection, then the broad, soft and moist sponge electrodes are rather to be

chosen. Success in this practice greatly depends upon these nice points. Mr. Thomas Hall, the electrical instrument maker of this city, has made for me, and other physicians and surgeons, a great variety of very handy and useful electrode instruments of this sort. (See Chapter IV.)* Thus I have endeavored to give here the *general principles* and some of the *minutiæ* to be observed in managing the *electric sitting* of a patient. (See p. 460.)

Faradaization.

Dr. Duchenne, of Bologne, is unquestionably entitled to the honor of having first of all introduced into medical practice the excitement of single muscles, or muscle groups by electric currents. The precepts, however, which are contained in his large work on the method of application of "localized electricity" appear far from being sufficient, either in number or explicitness. Dr. Duchenne, we observe, distinguishes two classes of operations; first, the *mediate* electrization of the muscles, through their nerve trunks; second, an *immediate* electrization, i. e., applying the electrodes directly to the single muscle, or bundle of muscles. The electrodes are in every case to be placed as near to each other as possible, while each of the two classes of electrizations requires otherwise different management. The technical terms he employs on page 47, to designate his particular method are, *direct muscular Faradaization, and indirect muscular Faradaization,* — which consist in causing every muscle or bundle of muscles to contract singly, by placing the moist electrodes, or *excitors*, as he terms them, on those points of the skin "which correspond with the surface of the muscle to be Faradaized." Nothing, he says, is easier than this way of Faradaizing, especially on the surface regions of the body and limbs, when the operator is acquainted with certain anatomical facts; but that it is more difficult with respect to the deeper layers of muscles, although almost all of them can be reached at certain places by direct excitement. The excitors should always be placed on the fleshy part of the muscles, but never on the sinews or tendons of the muscles. To Faradaize a muscle

* Compendium, ch. 1.

completely, it is necessary to embrace the whole surface of it by the excitors. The current must be strong in proportion to the thickness of the muscle.

This term originated with Dr. Duchenne; and I now proceed to give an account of his "*method*" of using *induction currents*, as explained in his large and popular work, *De l'Electrisation localisée, et de son Application à la Physiologie, la Pathologie, et la Therapeutique*, Paris, 1855. He first states, "that if the skin and the metallic electrodes are both perfectly dry, then the currents of induction do not penetrate into the subjacent tissues, but reunite on the surface of the epidermis; and that in this case there are produced *sparks*, (!) with a special crepitation, but no physiological effects." Now, we must mark this statement of his, for evidently he is employing a machine for producing induction currents, such as we never think of employing in this country for medical purposes. His method and rules will not therefore always apply to us, nor shall we be liable to meet with his mishaps, nor yet, perhaps, with his marvellous cures.

It may, therefore, be laid down as a rule, first of all, that *the* electricity which requires a given rule and regulation for its employment, as also those physiological and remedial results that are brought about by any prescribed method of use, are *determined, in part at least, by the kind and efficiency of apparatus used to provide the given electricity*. This proposition may be transposed thus: A correct *rule* for using one kind of electricity does not always necessarily apply for the use of another electricity, whether it relates to the kind as static or dynamic — to intensity or quantity — to Galvanic or to Faradaic electricity — to constant, inconstant, or alternated currents; nor will there follow the same safety or danger, failure or success. With our eye on the *kind* and *power* of current employed by Dr. Duchenne, we will proceed to pass in review his leading propositions and *modus operandi*.

When dry excitors are applied to the skin that is also dry, he says, there is produced a sensation of heat or burning only; but

if the skin is likewise thick, then there is no kind of sensation. If, then, the electrodes are wet, or the skin is wet, neither spark, nor crepitation, nor sensation of heat is produced ; but a phenomenon according to the position of the electrodes. If they are planted over the body of a muscle, then there is a contraction of that muscle, or at least of the superficial portion of it, together with a sensation that is not peculiar to the skin, but that always more or less accompanies the electro-muscular contraction. He defines this sensation as being like that produced by acting on a muscle that, for example, has been laid bare by a wound, so as to be no longer covered by the skin.

Again, if the electrodes are positioned over the course of a mixed nerve, then contractions of all the muscles animated by this nerve are produced. Hence the proposition for his two quite different methods of proceeding: first, by applying the electrodes directly to the body of the muscle ; second, by applying them rather to the nerve trunk that animates those muscles. The first method he designates as "*direct muscular Faradaization*," the second method as "*indirect muscular Faradaization.*" In both cases he directs that the electrodes and the skin should be wet. For this purpose he employs mostly large wet sponges, which are in part stuffed into the ends of hollow metallic cylinders, or handles, which are insulated on wood. But for limiting the electric force to and in a muscle of a smaller size, such as the *lumbricales*, *interossei*, or muscles of the face, he employs "small conical electrodes," which he more frequently terms "*excitors*," but which are simply *poles*, or *electrodes*.

But it was left for Dr. Remak, of Berlin,* to point out, and for Dr. Ziemssen to demonstrate, clinically and anatomically, those defined spots, which are found to correspond with the points of entrance of the motor nerves into the lateral borders or *edges of the muscles*.† The latter marked upon the skin of the patient, with nitrate of silver, such lines and spots as proved electro-muscular responsive,— to the there placed electrode,—

* Uber methodische Elektrisirung gelahmter Muskelen, Berlin, 1856.

† Die Electricitat in der Medicine, Berlin, 1857.

and then, after death, by dissecting the motor nerve branches to their entrance into the bundles of muscle fibres, he thus found that these two series of experiments agreed with each other perfectly, in every respect. Hence Remak and Ziemssen are both of the opinion that there is no muscular contraction by exactly direct localized electrization of the muscles, as Dr. Duchenne claims, but contend, on the contrary, that in every case the contraction is brought about by the interposition or coöperation of the muscle nerve.

The trunk of the *facial* (*portio dura*) *nerve* can be reached from the external opening of the ear, or after the nerve emerges from the stylo-mastoid foramen just under the ear, by placing one electrode between the *mastoid process* and the *condyloid process* of the lower jaw. But he thinks neither of these ways should be resorted to in cases of paralysis of the portio dura, because from that point in the ear the feebler currents produce no effects on the muscles of the face; while if we employ requisite currents to produce an effect on the face muscles, the electric stimulus is then inevitably conveyed to the superficial *temporal*, or to the *auriculo-temporal nerve* from the third branch of the *trigeminal* (*tri-facial* or fifth) nerve; whereby a very annoying pain is also produced. He, for that reason, advises seeking the nerves that branch from the *portio dura*, where they emerge from the parotid gland; or else limit the position of the electrodes to the individual muscles that are affected. He says he finds a slight difference in the exact situation of some of these face motor nerves, in some persons, but that the electrodes will soon discover them.

In the *supra-clavicular* region, the electrodes, if placed directly over the collar bone, act on the *brachial plexus*. If placed on the summit of the *supra-clavicular* triangle, they are then over the external branch of the *spinal accessory nerve* of Willis. The *phrenic nerve* is reached on the anterior surface of the *scalenius anticus*.

Dr. Duchenne also maintains that both nerves and muscles possess very different degrees of *excitability;* and for that reason

it is necessary to adjust the strength of the current *to the given excitability* of the nerve and muscle to be treated. He also mentions a difference of *muscular* sensation in different muscles while contracting. This he termed "*muscular consciousness.*"

To *Faradaize* the *skin* he recommends *three* principal processes. The first is by the "*electric hand;*" i. e., of the operator. The patient takes one electrode in the hand, and holds it during the *seance*, while the physician holds the other electrode in his leisure hand. After having dried the skin with flesh powder, the operator passes the back of his hand over the surface to be excited. A lively crepitation is the only phenomenon produced, except, perhaps, over the forehead and face, where it becomes painful. It is the advice of the author, whenever this is done, that the operator use the same hand that holds the electrode, so as to prevent the passage of so high an induction current through his own person, which is thus to himself highly injurious and unsafe to be so long continued, or often repeated.

The *second* process is by means of solid or "smooth metallic excitors," which are adjusted to insulating handles. The skin is to be dried as before; but if the epidermis is very thick or hard, as on the palms of the hands, then the skin may rather be a little moist. When it is necessary to produce a strong effect on a certain point, the excitors are held for a given time lightly in contact with the skin. These solid metallic excitors, he says, are often insufficient for the palms of the hands and soles of the feet, whatever intensity of current may be used. In such cases a bit of wet wash-leather over the face of the brass electrode will render it at once effective.

The *third* process of Dr. Duchenne is by means of the *metallic wires*, or "brush electrode" — a bundle of fine wires adjustable in the hollow end of the common electrode. The skin is quickly and more or less lightly tapped or beaten with the ends of this wire brush, while held perpendicularly to the surface of the skin. But sometimes it is necessary to retain them longer in contact with the skin, as in cases of palsy of sensation. Indeed, Dr. Duchenne recommends this for many cases of anæsthesia, neuralgia, and muscular rheumatism.

To *Faradaize* the internal ear, he advises one electrode to be on the back of the neck, and filling the ear tube with warm water, then introducing into the water thus filling the external ear, the wire tip of the primary or secondary conductor of an induction machine, and maintaining it in the midst of the water, while the current flows, but without touching the sides of the ear passage if possible, nor yet the membrane of the tympanum. But this is so difficult to be done, so disagreeable to the patient, and so ineffectual, that the author has instituted an entirely different method, by employing an *ear electrode* of ivory, sponge, and silver wire to convey the galvanic current, or the faradaic current, in this treatment for noises and deafness, which is more practical, agreeable, and more frequently successful. (See p. 262.)

For *Faradaizing* in partial amaurosis, loss of taste, and premature diminution of sight, he advises "the employment rather of the continuous galvanic current, because it exercises a very much more remarkable influence on these organs than can be produced by the induction currents of electro-magnetism." But how does Dr. Duchenne (and other writers who seem to take all his propositions without question) reconcile such facts, declared by himself? This is no declaration of another — no *ex parte* testimony. A late English writer testifies that he has found the best effects from the use of moderate *galvanic currents in affections of the special senses;* and yet, in the same work, he cautions against the employment of these same currents on the large nerves and muscles of the limbs, for fear of the effects reaching the brain! I cannot account for this opinion, if given from experience in practice, unless, as in the former case, — i. e., when using *galvanic* electricity about the face, — care was taken to use the smaller intensity, also the occasional, or, perhaps, more frequent interruptions of the current, as it certainly should be only so employed; while in the latter case a stronger inverse current was allowed to traverse a nerve trunk, or group of muscles, persistently for some indefinite time, which would almost necessarily do injury rather than good. To apply any considerable current of galvanism to the nerve

trunks, muscles, back, or head of a patient, and retain it there for some time, regardless of the condition of *variation, of density* of current, or of interruption, direction, or alternation, &c., would be a foolhardy and highly hazardous experiment. In my opinion no such current should ever traverse the part more than one minute at a time, at the longest, although repeated again and again in the same place and manner. (See Rule 8.)

The *Faradaizing* of the *diaphragm* for quickly producing artificial respiration is, according to Duchenne, best done by applying the one electrode over the *phrenic nerve*, which takes its rise from the third, fourth, and fifth cervical pairs, and is to be reached on the anterior edge of the *scalenus anticus*, and just at the back edge of the middle of the *sterno-cleido-mastoideus* muscle, while the other electrode is placed at the pit of the stomach, with a down-running current. Let the electrodes be wet sponges with large surface. The *instant* they are applied, the artificial respiration is usually produced; the thorax heaves, and the air rushes forcibly into the lungs; thus by applying and removing one electrode as often as this phenomenon is repeated, it is possible to keep up a respiratory process for a time, even after death. *Perseverance* must be the motto here; for in all cases of apparent death from water, strangulation, lightning, asphyxia, from chloroform, opium, carbonic acid gas, &c., to establish and maintain respiration, *is* often found *to save life*.

The *Faradaization* of the *larynx* is done by means of the small olive-shaped instrument, which is passed down (without the current) as far as the posterior and inferior portion of the larynx, while the other excitor, as in the previous cases, is then placed on the nape of the neck; or it is better sometimes to be situated outside, front of the throat, on a level with the *crycothyroid* muscle. Thus situated, they may receive the current gently at first, and at the same time the sponge is moved about a little. But he says the *indirect* method is easier, and often effectual. One excitor is in that case placed over the *inferior constrictor* muscle on the anterior portion of the throat, and so reaches the *inferior laryngeal nerve*.

Electro-puncture.

Electro-puncture is the sub-cutaneous application of the different forms of electricity. Thus acu-puncture needles become sub-cutaneous electrodes. One, two, or more needles inserted into the flesh may connect the circuit of a friction machine, either directly from the prime conductor, as an influence or aura, or through the Leyden-jars, as a mild or full shock; or they may connect with the poles of the galvanic battery; or with a faradaic machine, according as the indications of the given case may require.

Acu-puncture, simply of itself, is believed by many physicians of learning and experience to be nothing less than actual electro-puncture, though no primary or secondary current be brought to bear upon the inserted needles. That is, the needles passing through the skin and tissues to parts deep beneath, act, they say, as *conductors* for the insulated electro-nerve or chemical current, which has become morbid, and thus modifying the local action, and restoring the equilibrium in the given spasm or painful spot.

Electro-puncture needles are to be considered, then, as a peculiar sort of sub-cutaneous electrodes. Their employment, with a gentle current, is the ancient "*acu-puncturation*" intensified in results, without being made a tithe more painful. Not one needle in ten need be in the least painful. Patients uniformly bear it well. The result for *non* inflammatory pains, if not malignant or organic, is as promising as tooth extraction is for inflammation, while it is nowhere near so painful. The speedy relief, and the valuable cures thus sometimes made in long-standing and troublesome cases, are enhanced a hundred fold by this dexterous little process. Such, in fact, have been the results of my own experience.

In the hospitals of St. Louis, La Piété, and Hôtel Dieu, of Paris, I saw this operation of acu-puncture performed in a variety of ways, and for a variety of maladies; where, also, I was informed that it had been practised some thousands of times, and in every case without the occurrence of any unpleasant effect

beyond occasional faintness or pain — it generally occasioning only the sensation of a little shock or prick, or a slight smarting. The rule was to avoid active inflammations, and the coast was considered clear for this kind of treatment. Among the many distinguished advocates of this procedure is J. Cloquet, who has done and seen much of this practice, and he approves of it, decidedly, when judiciously performed. Even the puncture of nerves, he says, does no harm; the pain is generally but trifling, and speedily passes away. But should the puncture be attended with any considerable pain or smarting, the needle may be withdrawn, and reinserted in another spot. Indeed, whenever the insertion of the needle proves to be very difficult or painful, my own method is, to immediately withdraw it, and as quickly insert it again in some contiguous spot where it will pass easily, and with little or no sensation, excepting, perhaps, a prick or shock; for if the needles enter readily, that is, quickly, with little or no pain, and without much force, we may all the more surely calculate for a degree of success.

Numerous experiments and accidents show, also, that no inconvenience follows the purposed or accidental puncture of arteries or veins by fine needles. A few drops of blood, perhaps, may issue; but this is rare, and may be readily stopped by pressure for a few seconds with the finger. If there is slight ecchymosis, it soon disappears. However, the nerve-trunks and blood-vessels, tendons, fascia, and the periosteum of bones, are to be avoided in these operations. If there appears a halo of a red color, about the site of the needle, it will be without tumefaction, and will soon disappear. If a soft iron or steel needle is employed, it is somewhat more painful at the insertion, and considerably more so at the extraction, than unoxidizable needles; nevertheless, I should employ such in emergency. What good comes from sub-cutaneous injections may yet be proved to be, mainly, the combined action of an opiate with the electric or alterative action of the acu-puncture, produced by the point of the syringe.

Methods. — First, the insertion of the needle or needles for acu-puncture, electro-puncture, or galvano-puncture, may be

skilfully performed by simply *stretching*, or else pinching up a fold of the skin with the thumb and fore-finger of the left hand, and dexterously passing in the needle, without hesitation, close to the thumb pressure, and in an oblique direction. When once through the skin, it can be pressed forwards in any direction more deliberately. My experience leads me to say that it proves to be, so far, less painful to patients than anticipated; that they often exclaim, "Why, that is nothing; no more than a prick of a pin!" The effect on the economy is electric; some patients experiencing a sensation of shock to the whole body, but which may be neither painful nor very disagreeable. More frequently, however, the shock is only experienced in the parts about the puncture. In other, more numerous, cases, there is only a tremulous sensation, and a tremulous motion of muscle or muscle-fibres, that is visible as well as sensible. Sometimes there is a thrill along down the limb, or even to distant sensitive parts. Frequently, when inserting these needles in the cervical region, as for occipital neuralgia, or for torticollis, when the affection was complicated with sciatica or hysteria, the patient experienced more sensation in the arm, hand, hip, or knee, than at the point of penetration. So soon as the vibrations in the muscle cease, or in case no such effect is produced, we may proceed at once to introduce the chosen current, through the needles, into the deep parts beneath. But one needle may be required in some cases, a sponge electrode answering for the other. Only a very small electric current is to be employed.

The needles for these purposes should be from two to four inches in length, of an unoxidizable metal, *very fine* and sound, well polished, insulated, and sharp pointed. The point should be lance or slim spear shaped, so as to cut its way with the least pain and little required force.

Platinized, untempered, or soft-tempered steel needles, with a small knob or ring at the eye end, are preferable for all cases except for coagulating blood, as for varicose veins or aneurism. Such needles I obtained in Paris at one dollar each by the dozen. These I have had fire japanned, excepting the head-ring and some half inch at the point. This perfect insulation prevents the

electricity from leaving the needle at the surface, and so delivers it all from the point where directed. I have also employed gold needles, and *gilded, soft-tempered steel needles.*

But when such cannot be conveniently obtained, long, *fine*, steel sewing needles may be selected, and heated to redness, and then allowed to cool slowly in the air, so as to lose their brittleness, and be made safe. To test this, spring them well, and see if they are tough and reliable. Then polish them in emery cushions, and head them with sealing-wax, so that they shall never be lost in the flesh. Such needles do very well, provided they are not left in the tissues of the body more than ten or fifteen minutes at a time.

A handle with a steel socket, called *porte-aiguille*, or needle-holder, a convenient article for holding and inserting these needles, is manufactured by Drs. Codman & Shurtleff, the makers of elegant surgical and dental instruments, 13 Tremont Street, Boston. They can also furnish the best of acu-puncture needles, either of platinum, gold, zinc, iron, or steel, and suitable electric apparatus, with instructions.

As a general rule, the seat of pain, the rheumatic deposit, dropsical effusion, or palsy, &c., will indicate the place where the needle should be planted; but sometimes the knowledge of anatomy and physiology alone must guide us. The number of the needles to be inserted at once is left to the judgment of the operator; they may be from one or two to a dozen. Generally, the smaller numbers are all that a case requires. The frequency or repetition may be as soon or seldom as the urgency or abeyance of the given case demands. My method is never to leave a needle inserted longer than ten or fifteen minutes, in all, at any one *seance*. When the operation is well performed, the relief speedily experienced is remarkable and durable.

When employing static electricity through these sub-cutaneous electrodes, it is better to commence by *influence*, that is, with a continuous flow of electricity without noise or spark; or else by *drawing* sparks *from* the needle inserted; and when the discharge is changed from the negative end of the machine to the prime conductor, so as to *give* sparks of greater length and

strength, begin carefully with short and light sparks, and pass but few in number, say five, or a dozen, or more, and watch the effect.

When employing the primary current, as galvano-puncture, it is best not to use great intensity. From one, two, five, to ten elements are all that should be so employed, (except in cases of blood coagulation, as for varicose veins and aneurisms.) The coarse wires that lead from the battery to the helix in the faradaic machine may be removed, and the conductors put in their stead, so as to lead the *mild-quantity* current directly to and through the inserted needles, by simply touching the heads of them with the wire tips of the conductors. If several galvanic cups are in the circuit, or if the nerve is weak and sensitive, deep muscle-fibre contractions are readily produced. For blood coagulation we must use three of Grove's, ten of Smee's, twenty or thirty of Daniell's, or, what is better, the *extra current*, quarter strength, of the *Petit* medical battery, as manufactured by T. Hall, 15 Bromfield Street, Boston. The extra current of this battery will electro-plate, and do much work of the true primary galvanism, as well as yield the most powerful current of electro-magnetism. It is the most powerful little battery found in this country, and equals the celebrated Ruhmkorff's coil, that is run with the bisulphate of mercury.* (See p. 374.)

When employing the faradaic current, or the extra current of the faradaic machine through acu-puncture needles, it is best to begin with the smallest degree of strength, and so increase until visible muscle contraction or pain is produced. The wire of one of the conductors from the apparatus, at least, should never be fastened to the head of the needle, but adjusted in the operator's hand so as to make or break the current instantly. Indeed, often, as in palsies, and wherever increased nerve-action is sought for, this interruption and reversion of the current are very necessary. And it is obviously necessary in cases of sudden pain or cramp, as tonus will sometimes set in quickly, and when least expected. When this occurs while using any form of electro-puncture, by a suspension of the current for a few

*Compendium, p. 72.

seconds, or if aided by pressure, it will cease; and it then may be repeated with good effect.

The primary current through needles (galvano-puncture) from one, two, five, to ten cups of Daniell's battery, has in my hands given the most speedy and satisfactory results. But this is available only at an office. The next best is the *extra current* from a faradaic machine; and if this is not available, employ the common faradaic current, of a weak and bearable strength. My methods thus enable me to recommend an almost painless procedure, both as relates to the insertion and the current. Hence I would lay great stress on fine, long, excellent needles, dexterous insertion, and small currents of electricity skilfully manipulated.

It cannot now be questioned that electro-puncture does exert such an alterative or chemical power by electrolysis and catalysis over morbid nerve-action, morbid muscles, vessels, and deposits, as to materially modify the nervous action, the circulation, depuration, and nutrition, in those parts to which it is applied. Magendi regards electro-puncture as the remedy *par excellence* for obstinate neuralgia, old rheumatism, incomplete amaurosis, and other local, long-standing palsy. Sarlandiere employed electro-puncture for the above affections when uncomplicated with organic mischief or inflammation; and where such does exist, he advises that antiphlogistic local or general remedies should be premised.

In a paper recently read before the French Academy of Sciences by Dr. Shuster, of Germany, it is contended, indeed, that electricity is principally useful, as a remedy, only when it is introduced into the substance of the affected organ by means of electro-puncture. As such, he says, this remedy constitutes one of the most powerful and harmless agents we possess. He related complete success by this means in *varicose veins*, for dropsies, both *anasarcous* and *encysted*, and for *hydrocele*, *ascites*, (idiopathic and symptomatic,) for serous and synovial *cysts*, for *goitre* and *aneurisms*, for *chronic* gout, neuralgia, and rheumatism, for *partial* and *periodic* amaurosis, and especially for *palsy of the retina*, for *aphonia*, *nervous deafness*, &c.

Electro-Chemical Bath.

Sir Humphry Davy observed, as long ago as in 1807, that if he immersed his fingers in a glass vessel filled with distilled water, connected with the *negative* pole of a galvanic battery, alkalies were excreted from his body and deposited in the pure water; but if the positive pole was in contact with the water and fingers, then phosphoric, sulphuric, and hydrochloric acids were deposited, and could be detected in the distilled water.

Electro-chemical baths, known as "Dr. Vergenn's," and which figured in all the country for a while, were but the hasty result of an IDEA, put forth to the world by M. Poey, who relates the origin, treatments, and consequences. It seems that in 1852, a man occupied with electro-silver plating in the city of New York, having had his hands in a solution of the nitrate and cyanure of gold and silver, a severe ulcer was produced, which proved very obstinate of cure under the most active remedies. At last the patient plunged his hand into the electro-chemical bath, at the positive pole, that was being employed at the time for silver plating. After holding it there for a quarter of an hour, it was found that the metal plate connected with the negative pole was covered with a thin layer of gold and silver. Then, by a few more such applications, repeated day after day, the electro-chemical bath proved sufficient for the cure of the ulcer. Upon that hint was based an idea which soon grew into an hypothesis of great magnitude.

Dr. Poey, of some southern city, soon prepared a paper on the subject, which, in 1855, was laid before the French Academy in Paris, in which he asserted "*that it is possible to extract metallic substances out of the human body by the aid of electricity*,—whether such poisons had been taken as remedies, or had been lodged in the body by absorption from exposure in some of the different arts and trades."

The electro-chemical bath is administered as follows: The patient is placed sitting upon a bench of wood, which is fixed low in a deep and large metallic bath tub; all of which is in-

sulated from the ground. The tub is then filled with warmish water until the patient is up to the neck in it. If it is supposed that the patient is poisoned with mercury, or with silver, or gold, then the water is acidulated with nitric or hydrochloric acid; but if lead is to be extracted, then sulphuric acid is added to the water bath, in the place of the other acid. The galvanic electricity must be large, both as to quantity and intensity, and the long-continued, even current is the kind for this purpose. The negative pole is connected with the foot of the bath tub by a binding screw, while the positive electrode is placed in the hands of the patient. The positive electrode is made of iron, and covered with wet wash-leather or cloth, to diminish the calorific action of the large-sized series of batteries necessary to run it. M. Poey goes on to give a graphic description of the mode of its action. He says the current circulates through the patient from head to foot, thus traversing all the internal organs, not excepting the bones, taking along with it every particle of metal which may exist in the organism; then, by restoring the metal to its primitive form, and depositing it over the whole surface of the sides of the bath tub from the neck to the feet, but always more abundantly over against that part of the body where the metal is supposed to exist. As an instance of this, M. Poey affirms that he once saw from a patient who complained of pain in the arm, in consequence of having taken mercury, the exact size and shape of the arm depicted or electrotyped upon the side of the bath nearest that arm, from the deposit of the metallic molecules which came out of the limb. He also affirmed that he had drawn from the femur and from the tibia of a patient a large quantity of mercury, which, according to some physicians, had actually existed in these bones for fifteen years!

But to deny that the electro-chemical bath is devoid of all effects on the human body, aside from the alleged extraction of metals, is but folly; yet at the same time there are the strongest reasons for doubting its utility or safety, as it has been thus far tested. More than one instance has come under our own observation of the injurious consequences attending this unphilosophical use of such galvanic power.

Flesh-mellowing and Deep-shampooing are the best terms I can find to concisely express my peculiar method of *handling the flesh*, which I have found so valuable an aid in certain classes of patients. By these terms I do not mean simply moving the skin, as the scalp upon the cranium, nor a superficial gliding of the skin over the muscles, back and forth; nor do I refer to skin friction, as by crash towel or flesh brush; nor is it a simple chafing, or "*rubbing*," with the hands. These have their appropriate place and usefulness; but they are to be avoided in other certain cases as much as possible, because they stimulate the sensitive skin-nerves, and would here produce hyperæsthesia; while my real object just here is to reach the vessels, the muscles, nerves, and deep fasciæ about the bones, *without* chafing or exciting the surface.

Flesh-mellowing and deep-shampooing are performed by simply grasping in each moist hand a whole handful of skin and muscle, and thus squeezing and working them as one would in working putty or mellowing an apple; or one hand being applied to each side of the limb, or each side of the shoulder, or spine, for instance, and at the same time *see-sawing* them alternately, but simultaneously. That is, while gliding one handful upward, the other handful is as quickly and strongly jerked downward, in such a manner as to effectually move all the muscles and flesh even down to the bones. These manœuvres, in my estimation, are a most natural and effective ally to electrical treatment for certain classes of cases we have to treat. Our whole duty is not done, in certain cases, when this is neglected. It may be performed before, during, or after the *seance;* or at home by some *strong*, warm-handed nurse, friend, or servant. A very good time is just before retiring for the night. But it is hard work, and requires more strength than persons are often called to exercise, if continued for a quarter or half an hour *with a will*, as well as with the hands.

Flesh-mellowing and deep-shampooing not only aid electrical treatment in a given class of cases, but are a most efficient treatment by themselves in cases of tender and over-fatigued, feeble, flaccid, and trembling muscles, for atrophied or rheumatic

muscles, for asthenic palsy, and for contractions, provided the given case is not complicated with active spinal disease. I would not even except organic contractions in wasting muscles, if the damaged nerve has been already healed. These proceedings, together with electricity, are very valuable for coldness, either from injury or disease of nerve, or from want of blood circulation; in spasmo-paralysis, and for cold feet.

Shampooing, as ordinarily done, and *rubbing*, are of the greatest service as aids in the treatment of some cases; but, we repeat, it is not what is referred to here. To violently rub the part, as a barber rubs the head, will not do. According to Webster, *shampooing* is a Hindoo word, which means "*to rub and percuss* the whole body, and at the same time to flex and extend the limbs, and crack the joints, in connection with the hot bath." My method of flesh-mellowing, on the contrary, is rather a squeezing of the muscles, a gliding and a wringing of them around the bone, as thoroughly and as long as the patient can well bear. This is to be combined, or alternated, with certain electrical treatments for a certain class of affections.

That is, in suitable cases, we profoundly electrify the relaxed or sick muscles by a *hazing movement* of the wet-sponge electrodes; and in cases of contractions we direct the electricity mainly to the powerless antagonizing muscles and their nerve. Then, during the process, quickly dropping the electrodes, and placing the hands respectively on each side of the thorax, spine, or limb, as the case may be, and without chafing the surface, we repeatedly grasp handfuls of flesh for squeezing, and cause it to glide over the underlying bones in various directions for some minutes; then apply the electricity again, and so on, beginning rather gently at first, and then more roughly and thoroughly as we proceed, until there is a glow, and the patient feels comfortable and refreshed; but *never* so as to bruise the flesh.

The muscles are thus all exercised as well as the nerves; the blood in the capillaries of the muscles and fasciæ, all that is between the surface and the bone, gets thoroughly disturbed, squeezed out, and replaced by a fresh supply of blood nutriment. And the best single method for thoroughly arousing the

blood, nerve, and muscle inertia, is to mellow the flesh as a boy would mellow a lemon or an apple. Manipulate the flesh by grasping motions of the whole hand, as if it were dough or putty. Imitate the process of milking, only move the hands along a little each grip, and so compress and glide muscle upon muscle, and muscle and fascia upon bone, until all is aglow. Large and strong hands are required to do this well. No harder work, we say, can be found than this flesh-mellowing and deep-shampooing. It should be repeated several times with each sitting for electricity. I employ strong persons with large, warm hands for this purpose.

Large Dry-cupping. — This is another most valuable aid to electric treatment, by coöperating in profoundly affecting the spinal cord, and the roots of the nerves, as they come out from it; as also for joints and muscles. It is a new method, and cannot be appreciated unless I here describe it. True, it is but a dry-cupping process, simply on a grander scale; but, in effect, it is adapted and intended to produce a far more thorough and deep disturbance of the vessels, nerves, and underlying tissues than any ordinary cupping, wet or dry. Cupping, we know, affects directly, and mainly, the skin and superficial capillaries. In this grander process, through means of large-surface vacuum glasses, we are enabled to draw into the enclosed skin-surface a pound or two, more or less, of blood and fluids with the flesh; while under all this, deep down beneath the base of the great vacuum, the parts are exhausted, blanched; and thus are held powerfully compressed for a given time, which may represent extreme ebb-tide. Then, as the valve is opened, the glass is removed and the surface is rubbed, the blood rushes away, and washes away, and allows new fluids to return to parts where all had lain stagnant and sick for a long time before; and this may represent a flood-tide. Rushing the blood this way and that, through a part, is an active alterative process.

It is to be performed during the *seance*. Apply first the electricity, and then the *grand cupping*, with or without the *mellowing and deep shampooing*, for a few minutes each, and so alternately for several times; but, of course, only in certain

appropriate cases. These vacuum or exhausting glasses are altogether unlike those in ordinary use for cupping, both in *size* and *shape*. I had them first made to order, at the glass-house, with plump, smooth, and variously curved rims, so as to fit easily over uneven surfaces; for instance, over given points and hollows along the very differently shaped backs; for the neck, over joints, and the limbs; or over the bones of the sacrum; over the shoulder-blade, between the shoulders, or over the ribs. Large glasses with rims to fit on a level surface will not do. It requires quite a number, each of different shape or size, to make a good set. Some two dozen are as few as this work can be done with. I find I am using twice that number. The following figures will illustrate some of the *oval* and *oblong* shapes: —

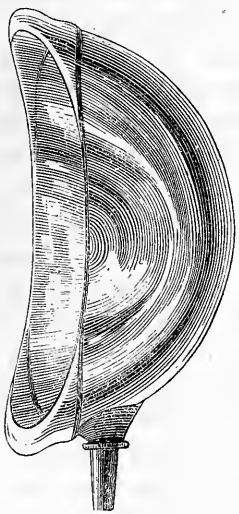


Fig. 110.

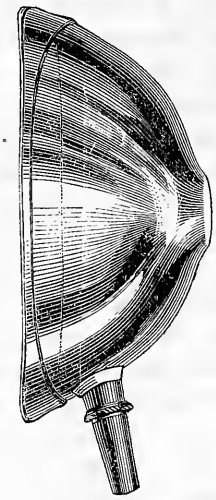


Fig. 111.

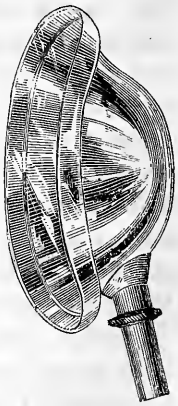


Fig. 112.

For applying over the loins of fleshy persons, over the sciatic exit, the stomach region, and the abdomen, I use a large, round, dome-shaped glass, that fits on a level surface, some six inches in every diameter — a quart cupping-glass. Others of this shape are five, four, or three inches in diameter. But the most of the set are *oblong* glasses, some six inches in length by three

in width; some more, others less, than this. Others have concave rims; others are oval, or oblique, so as to fit a twisted surface. One glass must be adapted to fit the deep groove of the back, as found in some persons, while others must fit over the poor or prominent backbones of other patients without hurting them; another is for the extreme hollow of some backs, or the bend of the side; for the crural exit, the cervical ganglia, or over the liver, or heart, or upper thorax, or base of occiput.

The exhauster is simply a noiseless india-rubber egg-shaped bag, that is worked by one hand, and obtains a good graduated exhaustion. The tube that contains the valve, and for attaching the glass to the elastic tube and egg, which latter has another valve at its outer opening, *is on the side*, as shown in the figures on the opposite page, and not on the top, so as to be conveniently managed under partial or loose clothing when desired.

Thus we can apply these vacuum glasses to the back, or any portion of the body, without undressing the patient. A man has only to undo the suspenders, unbutton the vest and waistband, and so pass it under the shirt, while sitting with his back to the operator on an ottoman. A lady need only unloose her clothing a little, without removing an article, when either the electrodes or the vacuum glass can be applied efficiently along any portion of her spine. True, it is easier to have freer access, and to see well the process. I only show thus what can be done, and well done. For this reason, too, I employ mostly my spoon-shaped electrodes, they do so facilitate the operations over the body and limbs, without so much uncovering the person — especially females. One can thus operate about the hip, the knee, or ankle, without having the limb entirely in sight. For I hold that it is as much the sacred duty of a physician to spare the moral sense, particularly of certain patients, or where there is in the given case any such sense to spare, as it is to spare pain or any other suffering.

Thus have I endeavored to delineate, in plain language, not only the outline, but even much of the *minutiæ* of my precautions and "*methods*" for the successful treatment of nervous chronic diseases. To render this more distinct for the young

practitioner, the following *rules* are also given; and to make the whole question of "*the medical and surgical uses of electricity*" more generally practical, the balance of this work will be devoted exclusively to practice.

Young medical gentlemen cannot be too early nor too deeply indoctrinated with the truth, that the uniformly successful practice of medicine depends as much upon the judgment and patience that carefully *executes the minutiæ*, or insists that the minutiæ shall be carried out, — it, the whole of it, and nothing but it, — as well as upon the grander and broader intellect and judgment that shall detect the disease, direct the plan of treatment, or choose the remedy.

A word more I wish to add here, by way of putting you on your guard, namely: beware of *overdoing*, in the applications of electricity. There is such a thing as an *inhibitory effect*, that is liable to be produced *in certain cases*, as those of extreme delicacy, exhaustion, and impressibility, be it termed reflex, or damaging. That is, for instance, when treating partial palsy in the active, or more late, stage of tissue transformation, we may hasten the process of destruction; or, if in partial palsy of the limbs, where the extensors are extremely weak, while the flexors are still active, if the current be too long, or too severely applied, it will produce a contraction, instead of extension, of the limb, although directed only to the palsied extensor nerves and muscles, and thus thwart the very end sought. If the ear, eye, uterus, or bladder is *too* strongly or *too* long electrified, it will stop all action — increasing the atomy instead of curing it, so that what little functional process there may have been remaining, can thus be utterly destroyed. With an eye on the constitution of the patient and the nature of the affection, you must seek, in every case, to avoid such results. But in the larger proportion of cases of nervous affections you may proceed more heroically, if only correct in the *direction* of the current. But *never allow the patient to hold the electrodes in his or her hands*, — not even one of them, — during the *séance*, except it be in treating that hand or arm.

FORMULÆ OF METHODS AND RULES.

A. *Directions for the Electric Sitting, or Seance.* — These explanatory notes are introduced here to facilitate others, less experienced, in the employment of electricity, by making very plain some of the *minutiæ* of the author's *method*, (in sitting the patient, in managing the electrodes, and guiding the current, as *by a law*,) during each of the different *orders* of sittings instituted by him for the different classes of diseases appropriately so treated, and for such found most uniformly successful. The *systematic rules* here laid down for employing electricity as a remedy, although not found elsewhere in this or in any other language, are not the mere idea of a theory, but are the apparently well-corroborated results of the author's own clinical experience. The word "*seance*" means the same as if we should say, "a sitting for electric treatment." In my office — since this has been and is with me *a special practice* — we have four different orders of attitudes for the "*séance*," (as it is termed by the French,) and for these we employ, —

1. The *insulated* chair and stool.
2. The cushioned *ottoman*, covered with rubber cloth.
3. The *invalid's chair*, with a head-rest.
4. The *lounge*, with pillows, &c.

To prepare a person on the first *order* of sittings, the clothes need to be tucked up from the floor, &c., so as to *insulate* the patient as perfectly as possible.

To prepare for the second *order*, the object is, *to get free access to the whole back, thorax, and abdomen.* If the patient is a boy or man, let him merely unbutton his clothes, and thus take his seat upon the ottoman, stool, or a chair turned sidewise, with his back towards the operator, his shirt and under flannel pulled up above the waistbands; while the latter takes his seat on a low stool behind the patient, with his table of apparatus close by, at his right hand. In this arrangement he can freely manœuvre the electrodes, up or down the whole back, side muscles, thorax, abdomen, loins, hips, &c. If the patient be a female, let her lift or gather up the back part of her skirts, as she is about to take the seat; the corsets and dress are to be loosened, and thus the hand of the operator can be passed freely up the back, or from the neck downwards; so also over the sides, chest, muscles, abdomen, and loins, as the case may require, — *without removing the clothing.* In this attitude we also have easy access for adjusting one of the electrodes under the nates, coccyx, Poupart's ligament, or on the lumbar region, while operating on the nerves and muscles of the thighs and lower limbs with the other electrode.

The *reclining chair*, or rocking chair, receives the patient for the third order, and is used for all operations about the face, eyes, ears, head, throat, &c.

The *lounge*, or sofa, or cot, is the fourth order, and is desirable for a variety

of cases, such as where there is a contracted hip joint; so also for some affections of back, rectum, bladder, uterus, &c.

A. Note 2. A very small quantity current, such as that produced by the Humboldt battery, may be maintained *continuously* during the night, or even for days, with happy effects. So also the compound primary current of a Pulvermacher's may be applied for 5, 10, 15, 30, or 40 minutes at a time, and even for an hour or so, as in tetanus and convulsions, provided the *power-coils* are proportionally few, or the application is not near or about the head. But the powerful primary current of *both quantity and intensity*, such as produced by a Daniell's or a Smee's battery, has so much *chemical* effect in living tissues, that — although perfectly safe, and highly useful, when applied for given cases, and by a precise *method*, for only a fraction of a minute — we must ever be reminded that *the long-continued application of such a current to the human organism is not safe, and is not its correct or philosophic use*; but in all the minute details of *current direction*, whether this way or that, applies equally well for all the primary galvanic currents, as for all the secondary or Faradaic currents.

B. Note 1. Experience leads me, of late, to conduct the electric treatment for many of the cases of neuralgia, rheumatism, "*sciatica*," and other *pain-causing conditions* of the nerves, muscles, and joints of the "lower limbs," — i. e. such as are not inflammatory, — under one of two general rules: —

Rule 1. *For Pains in the Lower Limbs in Obstinate Cases.*—Where the painful limb is *cold* and soft, or lean, and with poor circulation, and particularly if the pain, stiffness, and weakness is about the hip and thigh, and mostly or *only above* or *about* the knee joint, — the foot and ankle being weak, — in similar cases apply the current in a *direct* or *down-running* direction; always observing, in these cases, one other of my rules for neuralgic affections, viz.: to commence the application with the utmost caution and gentleness in every possible respect; also using only large, fine, soft, and moist sponge electrodes, (see pages 387–389,)* one of which (the *positive*) is to be placed, according to the nature of the case, over the exit of the great sciatic nerve, or under the coccyx, or a little above the second lumbar vertebra, or else *occasionally glided* from the one place to the other, searching for the most tender spots, over and about which, when found, this electrode is to linger; and at the same time applying the other (*negative*) sponge into the popliteal space back of the knee joint, where it is to be held for, say, 30 or 60 seconds, with a gradually increasing current; then gliding it along, so as not to interrupt the current, on to the external *peroneal* nerve trunk, in like manner; then move it along over the *extensor digitorum* with a full bearable current; then wiping it over the whole calf of the leg for a minute or so more; then on to and about the outer ankle joint, and so on to the roots of the toes, first above, then underneath, but without once intermitting or reversing the current. Here let this electrode rest; and now commence gliding the other, upper (*positive*) elec-

* Compendium, pp. 84–88.

trode downwards, from stage to stage, mostly following, and pressing it over, the course of the affected nerves, but also wiping it over the muscles of the thigh, and about the knee joint, on its way down, terminating the *seance* by working the sponge down to the ankle. If there is *arthritic rheumatism*, then pass a strong current also *through* the affected joint, in a direction downwards and outwards, and so maintain it for some minutes. If, however, the pain, soreness, weakness, or contraction is rather on the anterior and inner side of the thigh, then proceed as before; but, *from* the abdominal ring, crest of ilium, or exit of the great femoro-crural nerve, *to* the inner side of knee joint, for some time; then to the inner calf of leg, ankle joint, and inner edge of foot. Carry out these principles in all similar cases. If the case is a mixed one, or is not benefited by some three, or four, or half a dozen sittings, then try, or pursue the plan laid down in the next rule; but observe only the one rule or the other throughout any one seance.

RULE 2. *For Pains in the Lower Limbs.* — When the painful limb is plump, solid, and *warm*, i. e., when the tissues appear to be well nourished, particularly if the pains occur mostly or *exclusively below* the knee or ankle, or along the calf of the leg, or in the foot, apply the electric current, during the seance, in an *inverse* or *up-running* direction; always observing the same precautions, and usually first trying the method laid down in the foregoing rule. For these cases we must, therefore, plant the *positive* sponge electrode at the root of the toes, while the *negative* is at the same time directed to the external *peroneal* nerve, or inner condyle of the knee, or popliteal space; and so gliding it on over the *vastus externus*, and *gluteus*, to the great *sciatic* nerve trunk, or to the lumbar region; or else over the *rectus femoris* and *adductors*, to the *crural* nerve trunk, and from there to the lumbar region. Thus, at one of these places, let this *negative* electrode now rest; while, with the other, we proceed to work gently upwards, from half minute to half minute, from the foot, over the ankle, to the knee, and so on over the thigh muscles; and while here, the *negative* should be removed to, if not already at, the lumbar region, while the *seance* is being finished, by working the *positive* up to the groin, or ischiatic notch, and there retaining it a little, the whole occupying 5, 10, or 15 minutes. Let this be repeated daily, or every other day, until the patient is quite restored.

RULE 3. *For Pains in the Upper Limbs in Obstinate Cases.* — Neuralgia, rheumatism, and other *pain-causing conditions* of the nerves, muscles, and joints of the shoulder, arm, and hand, must be treated much on the same principle as already laid down, under two *rules*, for sciatica, &c., (for which see at B., RULE 1.) If, therefore, the case presents a painful shoulder or arm, that is *cold* and soft, or lean, particularly if the pain or lameness is *mostly* or *entirely* about the shoulder, upper arm, or elbow, in such a case apply the current in a "*direct*" or *down-running* direction. First, plant the *positive* sponge electrode on the cervical spine, while the *negative* is being directed over the

brachial plexus for a minute; then glide it along down the *pectoral* muscle to its farthest extent; then over the *median* or the *ulnar nerve*, near the elbow joint; then glide it along down the outer side of the fore-arm, to the back of the hand but a little below the wrist joint; then wipe it over the extensor muscles on the back of the fore-arm; and then in like manner over the flexors. Next allow this *negative* sponge to rest a little first in the palm of that hand, and then on the back of that wrist joint; and at the same time commence moving the upper or *positive* sponge that has been on the upper back, and with it bathe over all the shoulder, neck, and pectoral muscles, and then also those of the arm, down to the elbow, and particularly over the trunks of the median, ulnar, and circumflex nerves; and so finishing the *seance* by working the electrode down below the elbow joint on the fore-arm, while the other is still at that hand. If there is a *rheumatic* affection of the joint of the shoulder, elbow, or wrist, then pass a smart current *also through the affected joint* transversely, or rather obliquely, and mainly downward and outwards, for some few minutes more at each *seance*.

RULE 4. *For Pains in the Upper Limbs.*—If the patient presents a painful arm that is plump, firm, and *warm*, with good circulation, and more especially if the pain or lameness is *below* the elbow, and about the wrist or hand,—— for such like cases, if the previous rule has been tried and failed, then apply the current in an *inverse* or *up-running* direction; always bearing in mind my fundamental *neuralgic rule* regarding careful manipulation. Commence this *seance* by first planting the *positive* electrode over the *median* or *ulnar* nerve, near the elbow; then, with the *negative* sponge, commence bathing with electricity over the *deltoid*, the *biceps*, and *triceps*, and so on to the *pectoralis*, and then lingering for a minute over and about the *brachial plexus*; next wipe it over the shoulder muscles, and then let this (negative) sponge rest, or be moved a little about (not above) *the upper dorsal of the spine*, and at the same time gliding the *positive* sponge along from half minute to half minute, first about the elbow, then over the fore-arm, wrist, and hand, and then back again up the arm, from stage to stage, until it sweeps over, not only the whole arm, but also the pectoral muscles; and after lingering a minute, or so, under and above the clavicle, glide it upwards and backwards until it rests just back of the shoulder joint; then start the negative from the dorsal spine, and with it bathe over the lower spine with a stronger current; then also the *infra-spinatus*, *teres*, and *serratus magnus* muscles; thus following the course of those brother twigs of arm nerves which are distributed over the ribs on the side and lower front of the thorax. Thus ends this *seance*.

RULE 5. *For Paralysis in any of the Limbs in Obstinate Cases.*—We must know those *fundamental laws in electro-physiology*, viz., when the electrodes, with any form of electricity, are so applied to any portion of the *living* human organism that the current is direct, (down-running,) then the effect thus produced is *a modified polarity of the nerves and muscles so embraced;* also a *less nervous action*, or at least *less* "*abnormal*" nervous action, is obtained in the parts *at*, *about*, and *above* the *positive* electrode, while there is an *increased nervous action at*, *about*, and *beyond the negative* pole; and that if the direction of this current be reversed, i. e., so as to be *inverse*, (up-running,) then the results will be precisely the same, but in a reversed order also; i. e., *diminished* action below, and *increased* action above; moreover, that this effect is greatly increased, if the current, in whichever way directed, is now and then *suddenly* interrupted, if for only a moment at a time; and that all this is still further increased in effect, i. e., far more extensively and profoundly disturbing and impressing the embraced nerves, if not the whole nervous system, by *suddenly and repeatedly reversing the current*,

as well as interrupting it, and that in direct ratio to the intensity of the electric current so employed, and inversely to the want of susceptibility in the organism, or hinderance to the inworking of the current. Therefore, (these being facts,) for paralysis we are to direct one electrode — whether moist sponge, or metallic plate or ball, covered with wet cloth or buckskin — to the fleshy part of the affected muscle or muscles, while the other is planted over the large nerve, whose branches ramify that muscle, and thus run the current in a *direct* manner, from quarter minute to quarter minute. Let the *breaking* of the current be *suddenly* done, at the *switch*, or binding screw, and not by lifting off the electrode from the skin. So let the *reversing* of the current be done by the *switch*, or by exchanging the *contacts* with the electro-magnetic machine, or by the *key-board* of the galvanic battery, —i. e. metallic, — and not by exchanging the electrodes. Thus, for a few minutes, work up the polar molecular mobility of the affected nerves and muscles, and then for a few minutes resort to Faradaizing, not only the sick nerves and muscle, but also those adjoining, or even the whole limb; and thus alternately operating, more or less long and severe, at each *seance*, according to the strength of the patient and the effects produced. When we still suspect or fear EXISTING central disease and source of the malady, (although in doubt, or even hoping to find a better state,) then we must *not* resort to any *reversings* of the current, nor even to *sudden* intermittences; at least not to risk this until after trying several applications *on general vitalizing principles;* such, for instance, as laid down for hysteria, and for atony of the abdominal viscera, &c., (for which see Rule 14.)

Thus we can operate on a case so as not to disturb very much the central organs, i. e., the *brain* and *spinal marrow*, if we but employ gentle and moderate *direct* currents, as under *neuralgic rules;* but we make somewhat more effect if we *suddenly interrupt* the current, or twitch the muscles by it; and we make more *central* effect still if we also *reverse* that current, and still greater effect if the current is directed considerable of the time *towards the head*, particularly if the *negative* electrode is about the neck, or *near the head;* and the effect is heightened still more if such a current is occasionally interrupted and reversed for a little, but *maintained mostly in the up-running direction;* and the profundity of every such impression is, moreover, in direct ratio to the strength of the electric current employed.

If, therefore, any portion of the arm or hand is paralyzed, we must first place the *negative* electrode on the *brachial plexus*, or nerve *medianus*, and with the *positive* work a strong current over the neck, cervical and dorsal back, as well as over the pectoral and shoulder muscles, for a few minutes, and then, placing the *positive* stationary on the plexus or nerve, proceed with the *negative* to make such oblique passes and such interruptions and reverses of the current over the affected muscles as will bring them into full action. This may be followed up by Faradaization, at the same *seance*, with good effects.

If any portion of the leg or foot is paralyzed, we must first place the negative electrode over the exit of the ischiatic nerve, or over the femoro-crural nerve, (according to the affection,) and with the *positive* proceed to bathe electricity over the whole spine, back muscles, and bowels, using a smart electric current. After this, place the *positive* electrode stationary at one of those great nerves, and with the *negative* make such oblique passes and current reverses over the fleshy parts of the sick muscles as to cause them to freely contract; but always aim to bring this about with the least possible pain.

RULE 6. For *electrifying* any muscles, on the limbs or body, painlessly, take but one electrode in the hand, while the other electrode is at rest over the nerve-trunk, (as directed in the foregoing rules,) or else *take one electrode in each hand*, which is my more usual practice, and proceed to adjust, waver, or glide the one, or both of them, as necessary for diagnosis or for treatment. Even when working *team-electrodes*, that is, moving both along together parallel and simultaneously, if they are the large sponge electrodes, it is better so to hold and control them. But for performing Dr. Duchenne's method of *faradaization*, that is, when working a strong current through small, oval, or pointed *metallic* electrodes, for "*localized faradaization*," (reflex influence?) then we are to follow Dr. Duchenne's advice: *take both electrodes in the same hand* — apply, retaining them perpendicular, to the skin, or moving them along near together, parallel and simultaneously.

RULE 7. (For *general* rules, insisted on by the author, see pp. 427–437.)* For "*tic douloureux*," i. e. after correcting the faulty function, or whatever is the provoking cause, — so also for *rheumatic face-ache*, periosteal jaw or teeth-ache, earache, for diffused hyperæsthesia, or peripheral neuralgia, &c., — the best method to be pursued in these cases is, to begin by placing the *negative* sponge electrode down inside the loosened dress at the pit of the stomach, or better still if at the lower umbilical region; then with the *positive*, a fine moist sponge, conveying the most gentle or even imperceptible current, and if electro-magnetic, let it be of the finest vibrations possible, — thus commencing on the side of the neck, gliding it about there thoroughly, then along up to, and a little in front of, the ear, and then on to the face, by wiping it over as if washing; then work back again to the neck, and now gradually increase the current while there, lingering some at and about the exit of the *portio dura;* then working the sponge along upon the face again, with the stronger current, by gliding and hitching motions, — say every quarter minute, — and thus for some 5 minutes, lingering mostly about or over the most painful spots. If there is then still any decidedly painful or tender spot left, choose a smaller sponge-tipped electrode *positive*, and plant it moderately firm *directly on the site of pain or soreness*, which is most likely to be found at the *supra-orbital* or *infra-orbital* nerve exit, and retain it there for 3 to 5 minutes, with all bearable current, — be it more or less, — until the pain and soreness are completely chased away. Always avoid touching the forehead with an electrode, because the periosteum of the bone is so near the skin that more pain is produced than relieved. I usually finish such a *seance* by wiping the larger sponge electrode again a few times over that side of the face and closed eyelids, and then passing it on to the side of the neck for the last minute. Now, if the pain returns at any time within 6 hours, repeat the treatment. If it does not return within that time, it is probably cured. But if it persistently returns, time after time, in spite of this treatment, you in all probability have not corrected the functional or habitual *cause*, or else you have in that case organic disease.

* Compendium, pp. 125–135.

RULE 8. (See pages 432, 443, 529, 550.)* My experience in the treatment of *cephalalgia*, or *head-pains*, and the various "*ugly and disagreeable feelings in the head*," those that occur *at the back of the head and neck*, arising from what I conceive to be *a "disguised" neuralgic condition of the ganglionic nerves in the head, or of the occipital nerves*, (but sometimes from this unrecognized condition of the *supra-orbital* nerve,) leads me to advise, as a general rule, to first pass the large sponge *negative* electrode well down the back, inside the loosened clothing, or else up under the clothing from below, so as to be beyond the cervical ganglia; and if as low as the *cauda equina* (second lumbar) is better still; then with the other large moist sponge *positive* electrode, commence over the cervical region, increasing the current to all that is bearable, (painless,) and thus wiping over the whole *sides* and back of the neck, slowly back and forth, without much rest, as far as to the shoulders, for some few minutes; then resting it from half minute to half minute, at or just below the most sore or sensitive places, at the base of the head, close to the hair, back of the ears, and on the posterior edge of the *sterno-cleido mastoideus* muscles. If the person is not nervous, and the first few *seances* do not effect the case decidedly, then for once apply at a future sitting the large sponge *positive* electrode, and only a very gentle current, *to the crown of the head*, and upon the *parietal* protuberances, through the parted hair, where the spots must also be a little wet; retain this current and site of electrode some 2 or 3 minutes only, *well back* upon the top of the head. Moreover, sometimes change the site of the *negative* electrode *to the epigastric region*, while directing the small sponge *positive* to the *supra-orbital* nerve exit; also while more strongly bathing the neck and shoulders as before; *but never while the positive electrode is on the top of the head.* In this latter case — a procedure I seldom resort to — the *negative* must be somewhere down the back.

RULE 9. (See pages 432, 443, 1015.)* *For operations about the eyes with electricity*, for "*heaviness*," *weakness*, premature "*poor sight*," or *paralysis* of eyelids, or for partial *amaurosis*, &c., we must proceed very differently from the method laid down in Rule 8. Here, we have diminished nervous action; there, was exalted nervous action. True, I usually commence the *seance* by placing one electrode first at the epigastrium, and then at the lower cervical back, and with the other medium-sized sponge begin wiping over the closed eyes, face, and temples repeatedly, but as carefully avoiding the forehead; first with this electrode as *positive*, while searching for pain, tenderness, and the *bearableness* of the case; then with it as *negative*, for a minute or so longer; and if the current is electro-magnetic, let it be gently increased as strong as can be used, without producing pain or any kind of suffering. For some cases, both the electrodes can be applied to the eyes, and exchanged back and forth, with good effects, in working up the nervous tone and muscular response. This may become still more effective by reversing the current by the *switch* or *pole-changer*, instead of exchanging the site of the electrodes. Next we are to exchange the large or medium sponges for the more delicate

* Compendium, pp. 130–141.

ivory electrodes, whose pea-sized sponge *tips* are wet with clean water only. These are to be placed — the one at the outer and the other at the inner angle of the closed eye, above or below, so that the current may traverse the nerve branches that ramify the *orbicularis palpebrarum*, as well as the fibres of that muscle, and the eyelids, and other tunics and glands about the eye, *when the electrodes are held lightly ;* or through the deeper parts, and the eyeball itself, *when these electrodes are more firmly pressed, so as to embrace the globe between the poles.* This effect is still more profound, if they are planted firmly at the outer corner of each eye, and the current is suddenly reversed; and still more so, if the positive electrode, a large sponge, is placed at the back of the neck, while the other, a smaller sponge, is pressed upon the eyeball, so that the current passes through the closed eyelids; and this is still greater, if the current is occasionally — say every quarter minute — suddenly broken and *reversed,* for a second or so, but *maintained mostly so as to run from the nucha to the eye,* thus producing true ganglionic reflex action.

RULE 10. (See pages 274, 435.)* *Operations about the genital organs.* For electrifying the rectum, urethra, bladder, vagina, or uterus, as required for cases of *atony,* or weakness, for *prolapsus, enuresis,* local palsy, &c., we may employ long, slim, insulated silver, or glass, or gutta percha electrodes, with sponge or silver tips, made expressly for these purposes, and which, for such cases, must be connected with the *negative* pole. (See page 1071.) The other, *positive* pole, may be a moist sponge, which, with a moderately brisk current that is often intermitted, and occasionally but for a moment *reversed,* (see cuts on page 389,) is to be moved, every quarter or half minute, up or down the back, in short stages, and in an elliptical order, (see Rule 14.) i. e. up one side of the spine, and down the other; then *vice versa,* and so over the roots of all the spinal nerves, *and their respective ganglia;* and finally along the sides of the body, and over the abdomen, during this part of the *seance.* Next, exchange the *internal* electrode for a surface sponge electrode, still *negative,* and by bringing the two near together, make them to promenade up and down the back a few times, with quite a strong direct current; then move them in small double circles over spine and back muscles; then, leaving the *positive* at rest on the back, or rather now and then moving it a little, proceed with the *negative* to bathe over the lower bowels, with very sharp currents, for some time, and so finish this *seance.* I should have said that this latter procedure has been my most successful method for *atonic Amenorrhœa.*

RULE 11. When the aid of electricity is resorted to in midwifery practice, as it is and can be most judiciously and effectively performed any where, and by any earnest practitioner; for instance, as for those cases where "the waters have broke," and hours have elapsed, and yet, notwithstanding the hot tea, the *room promenade,* and a well-dilated *os uteri,* still the labor does not set in in earnest; or where the pains have been for some considerable time "*grinding*" and unavailing, the harassed patient and every one else is being "*worn out,*" and yet the labor has scarcely progressed; also in those cases of

* Compendium, p. 133.

tedious labor, just as the moments arrive when it becomes evident that the powers of the patient must soon fail, or be speedily and effectively aided by this force of nature, (electricity,) or else by ergot or instruments, or by all these, and more; so, moreover, in *post partum* "*flooding*," when occasioned by *atony*, want of vitality, or excessive fatigue of the womb and abdominal muscles; thus, wherever it is desirable to promote tone and *true* "*labor-pains*," let the woman lie upon her side, while the operator, with a *brisk working* electric machine, (electro-magnetic, or magneto-electric,) takes his position with a large sponge electrode in each hand; the one, *positive*, is passed to the upper spine, from whence it is to be diligently moved about over the whole back and ribs, sides and breasts, while the other, *negative*, is directed to the abdomen; and thus with the two, separately performing the double circle movements simultaneously, (see Rules 13 and 14.) the one on the back and thorax, the other over the abdomen; which latter is to be moved in short stages, and so swept well about the gravid uterus — *not continuously*, but from half minute to half minute — for some three or four such moves, (or until a true pain is induced,) and then give a recess of a half minute or so; and then repeat it in like manner, and so on, again and again, until true *labor-pains* are established, or the desired object is obtained. Sometimes the electrodes may be placed to advantage, so as to embrace the projecting abdomen transversely, obliquely, &c., for a little, but mostly as just advised. Sometimes it is important to trust one — say the electrode on the back — to the hands of the nurse, that the accoucheur may have one hand free. Where there is *no contra-indication*, the effects of the already strong current is greatly increased here, by a *sudden, occasional, and momentary stopping and reversing the current.* (See Rule 5.

Rule 12. *Not so* must we proceed, if the affection, on the contrary, is a *painful, irritable*, and probably a rheumatic, or a neuralgic one; for then we must invariably connect the abdominal, or *internal* instrument (electrode) with the *positive* pole, while the *negative* sponge is now directed to the terminal twigs of the femoro-crural nerve, on the inner side of the knee joint, — first on one, and then on the other; also moving this one about occasionally upon the thigh muscles, but without shock, — i. e. without producing a break in the current, — although it is well to vary its strength during the *sitting*. Neither is it always necessary to resort to the internal electrode for these cases. Indeed, I think I can safely state, that in the great majority of cases the treatment has been completely successful, where it was conducted with *only* the large moist sponge electrodes, the *positive* of which was directed to and about the lumbar region, the crest of the ilium, to the abdominal ring, groins, and thighs, and so terminating each *seance* while working both electrodes as low as the knees or ankles. Thus we are enabled to employ a very much stronger current, and also spare the moral feelings of the patient. Therefore I would further say, that for pains, weakness, "*ugly feelings in the small of the back*," or on the sacral bones; for neuralgia of the spermatic

cord, testicle, scrotum, bladder, &c., in the male; or of the fundament, labia of the vulva, urethra, vagina, uterus, or ovary, in the female; as also for neuralgic lumbago, and for *dismenorrhœa*, (see page 933,) we are to commence the treatment by placing the *negative* electrode low down on the inner side of the thigh or knee, while with the *positive*, directed to the *cauda equina*, (second lumbar,) we perform circle movements on and about that part of the back for a minute or so; then removing the *negative* to the outer side of the thigh, and increasing the current, glide the *positive* up and down the whole back, about the loins and abdomen, until all pain, tenderness, and lameness are entirely wiped away. Next, return the *negative* to the inner side of the thigh again; and now pass the *positive* over and below the crest of the ilium and lower flanks of the abdomen, — lingering or working most, near, about, and over the most painful or tender spots, with a lively current, but not so as to cause much pain. Next, work it on the groin, inner and upper part of the thigh, and so on downwards, cautiously watching for any expression of new-caused pain; for this must be avoided. If, after several such treatments, there is obtained no substantial relief, then, perhaps, we are justified in also entering the private organs with suitable electrodes. This should certainly be done in the more obstinate cases. But I maintain that we may very much more frequently succeed without this last resort. This is peculiarly true as regards *amenorrhœa*, under Rule 1; and of *dismenorrhœa*, under Rule 2.

Rule 13. (See page 427.)* *Circle Treatments.* — Some of my most valued and frequently resorted to *methods* of manipulating the electrodes are termed the circle movements. These are performed, for specific ends, in several different ways: first, by the *single circle* movement, — i. e., usually done by one electrode, while the other remains stationary, — the *positive* being planted in the centre of the circle-making *negative*, or else situated more or less distant, according to the anatomy and the affection; or by *double circle* movements, — i. e., both electrodes are moved in circles, — the *positive* in a small circle *within* the larger circle of the *negative*, as if about a common centre; or by *alternate circle* movements on separate parts; or by *simultaneous circle* movements, — as for instance, where one, *positive*, electrode is on the back, while the other, *negative*, is on the stomach or bowels, performing smaller or larger circles there, and alternately, or at the same time, the former is moving elliptically up and down the back, or over a portion of it. Thus it is seen they accomplish specific purposes, and for the given case one cannot be substituted for the other; besides, we are thus enabled to very surely bring under the searching influence of such gliding and gently varying — although pretty smart — electric current, all the muscle-fibres, through and together with the nerve trunks and their depending branches, as each becomes successively embraced between the two relatively changing electrodes, or as they receive the influence — within or beyond — of the sweeping electric radius.

There is another *double circle and seesaw method with team-electrodes*, that we often employ, as in Faradaization; as for *dermatalgia*, or neuralgia of the

* Compendium, p. 125.

skin, and for hyperæsthesia of the sentient nerves. For this the electrode must be small, and the electro-magnetic current must be as sharp as the patient can possibly bear. (See Rule 19.) *Team-electrodes* is merely a term I employ to signify that mode of holding and moving two small electrodes in the same hand, with only a finger or two between them, as first performed and described by Dr. Duchenne, in his *localized Faradaization.*

Rule 14. (See pages 928, 954.) *The General Tonic, or Vitalizing Seance.* — This was instituted by me at first only for cases of general debility, incipient decline with weak chest muscles, and nervous cough; for emaciated children, and young persons with cold skin and poor circulation, as after severe sickness, and for *general hysteria.* But the past year or two I have found it also *the treatment* for rachalgia, (*irritable spine,*) rheumatism of the vertebræ, and hyperæsthesia of the back muscles, as well as for atony of the abdominal viscera, for constipation, &c. (See *law* of electro-physiological action, on page 921.) The patient is seated upon the ottoman or stool, and the operator takes his seat behind him. The *negative* electrode sponge is first directed to the umbilicus, or, if a female, to the left ovary, perhaps, while the *positive* moist sponge is firmly held, and slowly glided over the whole back, shoulders, and thorax, for a few minutes; then increasing the current still more, (*more* in proportion as the patient is *less* nervous,) carefully, but considerably, and now moving the two electrodes all the while in less or greater circles, the one on the back, shoulders, or thorax, the other on the abdomen or thighs, and otherwise modified to the case, — *but always observing the same relative current direction,* — thus *depolarizing* the roots of the spinal nerves when exalted, and arousing the peripheric nervelets when diminished, and calming or "*modifying*" the great chain of ganglia in the sympathetic department of nerves! Now, the evidence that this or its equivalent is obtained, — whatever it may be termed, — is the almost uniform fact, that after such repeated sittings, either alone, or as aid, or aided by other judicious medication, the ovaries are found not so sensitive, and the catamenia flows more promptly and easy; the bowels are not so tardy, muscular tone is awakened in the abdominal parietes, — i. e., there is not that baggy sensation, or constricted condition of the abdomen and its contents, — digestion (and secretion?) is invigorated, and there is evidence that the muscles of the back and sides, as well as the vertebræ and ribs, are less sore, less tender to touch or pressure, and the whole body and limbs are less lame, and not so "*tired;*" and if there has been hysterical or hypochondriacal manifestations, they are vanquished. The patient shows more interest, courage, and purpose of will or resolution, as well as powers of endurance. In a word, so uniformly is this the result of a few weeks of such electric treatment in suitable cases, that we here urge its use, by competent practitioners, as a most valuable adjunct medication, and well worthy of patient investigation, and improvement or adoption.

Rule 15. (See page 433.)* For *Thoracalgia* and *Infra-mammary Pain,* take the following method: First place the *negative* electrode at the

* Compendium, p. 131.

lower umbilical region, then with the *positive* sponge commence under the clavicles, bathing over the pectoral muscles, for a minute, and then over the whole thorax; mainly, or only, I should have said, on the *anterior* portion of it, — employing only medium strength current, and working *at first round about* the sore or painful places, then on to them, as well as about them, for 5 or 6 minutes more, or until all pain and soreness is chased away, so as not to be reproduced by full inspiration. Repeat the same daily a few times.

RULE 16. (See page 433.)* For *Epigastralgia*, and pains simulating dyspepsia, adopt the *double circle movements*, by placing the *positive* moist sponge *near* the tender spot over the stomach, while the other, negative, is placed somewhere below, on the abdomen or thighs, — i. e., far away, and that in a downward direction, — and thus commence moving both electrodes in circles, the one close about, and afterwards over, the tender stomach, while the other is performing a large part of a larger circle, and that mostly in a downward direction, which is to be continued for 5 or 10 minutes. The *positive* sponge must be moved as gently but as firmly as possible, without producing pain. Repeat this *seance* daily, or every other day.

The foregoing rule, with the use of the wire-brush electrode, is the correct *process* for many cases of *irritable spine*, *local hyperæsthesia*, *rheumatism*, and *injury* of spine or ribs, (after leeches, cups, or blisters, where is inflammation) by operating close about and over the seat of pain or soreness, with the *positive* electrode, in like manner as described for epigastralgia, — say for 5 to 15 minutes, — always observing in such cases to work the *negative* electrode mainly in lateral and *downward* directions, — i. e., to the parts anterior and below the seat of difficulty. Such is the principle.

RULE 17. *For Local Palsy of Sensation.* — First employ double-circle movements, with large sponge electrodes, the negative in the centre, so as to exercise the underlying muscles. This may occupy some five minutes. Then follow with the method as laid down for paralysis in the limbs. Next, smartly faradaize the surface of the delinquent part through the wire brush. Repeat all this daily, or less often.

RULE 18. (See page 564.) For *Cœlialgia*, or pains in the skin, fascia, and muscular tunics of the *abdomen*, first place the *negative* electrode at the inner sides of the thighs, or as low as the inner condyles of the knee joints, first on one, and then on the other, while with the *positive* perform circle movements about and over the affected part of the abdomen. But here be careful to distinguish such pains, from those that arise so severely, and not unfrequently, *from atony and relaxation of the underlying viscera*, as when the intestines give way to flatus or excrements, or as where, under a morbid nervous action, there is a *secreted* flatus in the bowels, uterus, or vagina, or there may be only a want of tone adequate to the free physiology. In these cases, therefore, we must, on the contrary, institute the methods laid down in Rule 5, the last paragraphs.

RULE 19. For *dermatalgia*, (a neuralgia of the skin,) as also for *local*

* Compendium, p. 131.

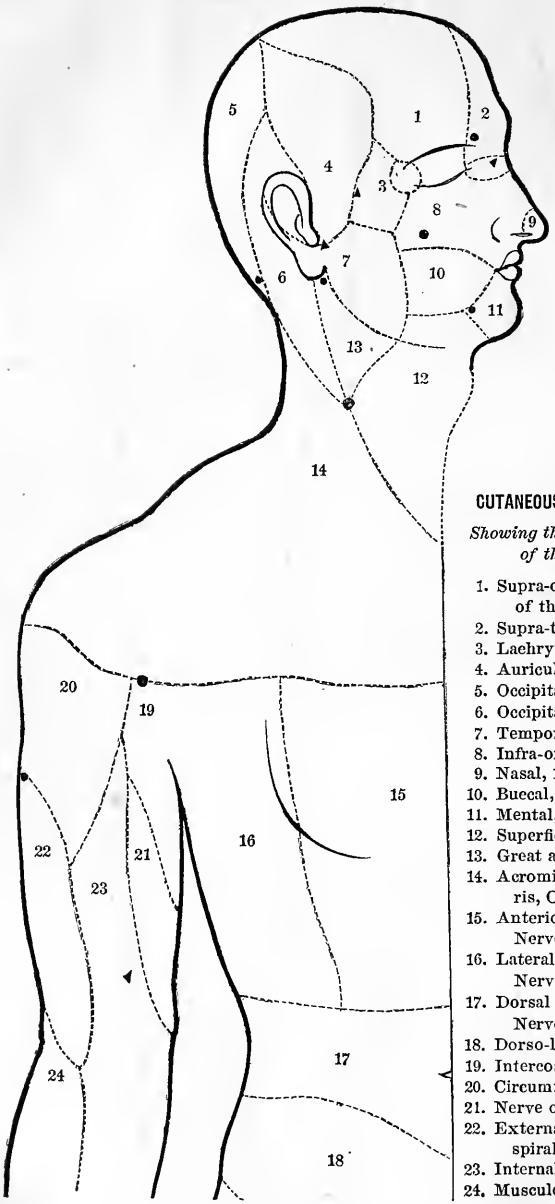
hyperæsthesia, of the sentient nerves, we may proceed in some cases by the direct and profound *electrifying process* through large sponge electrodes; or by the *faradaizing process* through small metallic electrodes; and in some cases employing both — that is, instituting first the one and then the other, *at the same seance*. *Electrifying* the whole of any given part (including the skin, muscles, and nerves) is performed by using large moist sponge electrodes, and a smart current, be it primary or secondary. Apply the electrodes boldly, directly upon or about the painful or sensitive spot, and holding, or gliding them firmly, so as to cause the action to freely exercise the underlying muscles by decided electro-muscular contractions. This, whether a reflex action or not, succeeds admirably, sooner or later, in very many cases. For this purpose we are to moisten the sponge electrodes in *formula* 34. But if there is in the given case a spinal irritation or congestion, or if there is a general state of hyperæsthesia, this process will fail — as it often does, also, in persons with a neuralgic diathesis or state, who are frequently or constantly subject to transient wandering twinges of neuralgia. The faradaizing process is here equally unsuccessful. These patients require *preparing* for the electric treatment; then the remaining *local* pains, or hyperæsthesia, are readily chased away. (For the faradaizing process, see pages 426, 438.)*

Rule 20. *Shocks*, or a sudden flow of electricity, may sometimes be required, as in cases of cold, insensible, and dropsical joints or limbs; or through the pelvis, as in amenorrhœa. (See p. 938.) The friction machine and Leyden jar can do this; so can the galvanic, or faradaic apparatus. With either of the latter, first adjust the large sponge electrodes, the one positive, and the other negative, all correct. Disconnect one of the conductors from its binding-screw; then set the battery working at some high degree of speed, and touch the wire tip of the conductor to its binding-screw repeatedly, slow or fast, and as many times as the case may require. This will shock a joint, a nerve, a limb, or the whole person, as effectually, perhaps, as any ordinary friction machine, and far less disagreeably.

Do not fail to have that kind of an electro-magnetic machine that yields, also, the *extra* current sufficiently strong to be felt in the hands, and to produce muscle-contractions, when required. Purchase no other. You will very often need this extra (one-way) current, in the absence of a compound galvanic battery, for most of the neuralgic cases.

Finally, beware of producing an overwhelming (inhibitory) or exhausting effect by any of the applications of electricity. True, very great power must be employed, in certain constitutions and diseases, in order to work a cure; while in other temperaments and affections our safety and success lies only in the prudent use of electricity, both as regards the strength of the chosen current as well as the length of time employed in its application at each *séance*. In doubtful cases you must vary, or alternate, the treatment in this respect, and so, as it were, feel your way to the appropriate *degree* best adapted to the given case.

* Compendium, pp. 124, 136.



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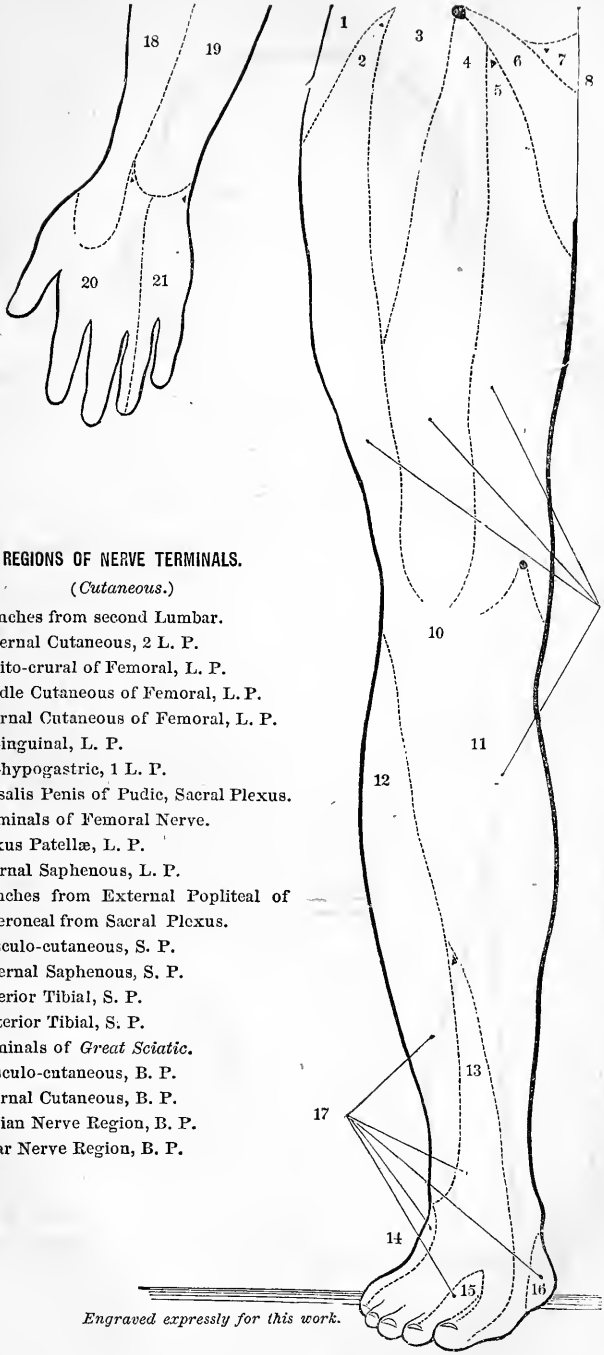
CUTANEOUS TERMINALS OF NERVES:

Showing their origin and the region of their distribution.

1. Supra-orbital, from first branch of the Fifth.
2. Supra-trochlear, 1, V.
3. Lachrymal, 1, V.
4. Auriculo-temporal, 3, V.
5. Occipitalis Maj., 1, 2, 3 Cervical.
6. Occipitalis Minor, C. P.
7. Temporo-malar, 2, V.
8. Infra-orbital, 2, V.
9. Nasal, 1, V.
10. Buccal, 3, V.
11. Mental, 3, V.
12. Superficialis colli, C. P.
13. Great auricularis, C. P.
14. Acromialis *et* Supra-clavicularis, C. P.
15. Anterior branches of Intercostal Nerves.
16. Lateral branches of Intercostal Nerves.
17. Dorsal branches of Intercostal Nerves.
18. Dorso-lumbar branches.
19. Intercosto-humeral.
20. Circumflex from Brach. Plexus.
21. Nerve of Wrisberg, from B. P.
22. External Cutaneous of Musculo-spiral, B. P.
23. Internal Cutaneous, B. P.
24. Musculo-cutaneous, B. P.



REGIONS OF NERVE TERMINALS.

(*Cutaneous.*)

1. Branches from second Lumbar.
2. External Cutaneous, 2 L. P.
3. Genito-crural of Femoral, L. P.
4. Middle Cutaneous of Femoral, L. P.
5. Internal Cutaneous of Femoral, L. P.
6. Ilio-inguinal, L. P.
7. Ilio-hypogastric, 1 L. P.
8. Dorsalis Penis of Pudic, Sacral Plexus.
9. Terminals of Femoral Nerve.
10. Plexus Patellæ, L. P.
11. Internal Saphenous, L. P.
12. Branches from External Popliteal of Peroneal from Sacral Plexus.
13. Musculo-cutaneous, S. P.
14. External Saphenous, S. P.
15. Anterior Tibial, S. P.
16. Posterior Tibial, S. P.
17. Terminals of *Great Sciatic.*
18. Musculo-cutaneous, B. P.
19. Internal Cutaneous, B. P.
20. Median Nerve Region, B. P.
21. Ulnar Nerve Region, B. P.

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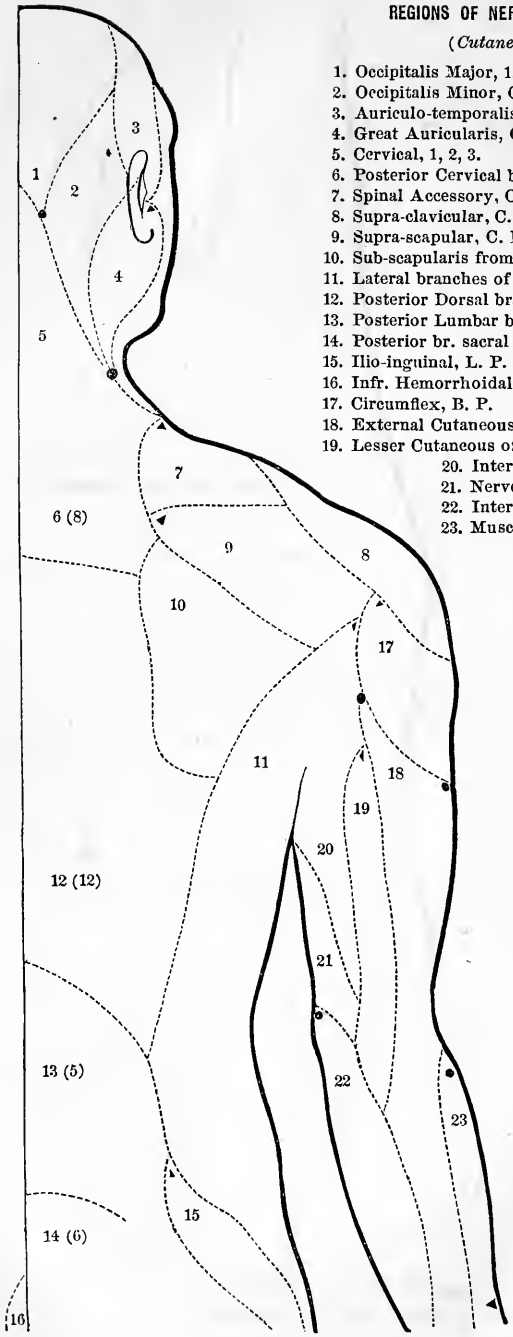

REGIONS OF NERVE TERMINALS.

(*Cutaneous.*)

1. Occipitalis Major, 1, 2, 3 C.
2. Occipitalis Minor, C. P.
3. Auriculo-temporalis, 3, V.
4. Great Auricularis, C. P.
5. Cervical, 1, 2, 3.
6. Posterior Cervical branches (8).
7. Spinal Accessory, C. P.
8. Supra-clavicular, C. P.
9. Supra-scapular, C. P.
10. Sub-scapularis from Posterior Cord of B. P.
11. Lateral branches of Intercostal Nerves.
12. Posterior Dorsal branches (12).
13. Posterior Lumbar branches (5).
14. Posterior br. sacral (6).
15. Ilio-inguinal, L. P.
16. Infr. Hemorrhoidal of Pudic, S. P.
17. Circumflex, B. P.
18. External Cutaneous of Musculo-spiral, B. P.
19. Lesser Cutaneous of Musculo-spiral, B. P.
20. Intercosto-humeral.
21. Nerve of Wrisberg, B. P.
22. Internal Cutaneous, B. P.
23. Musculo-cutaneous, B. P.

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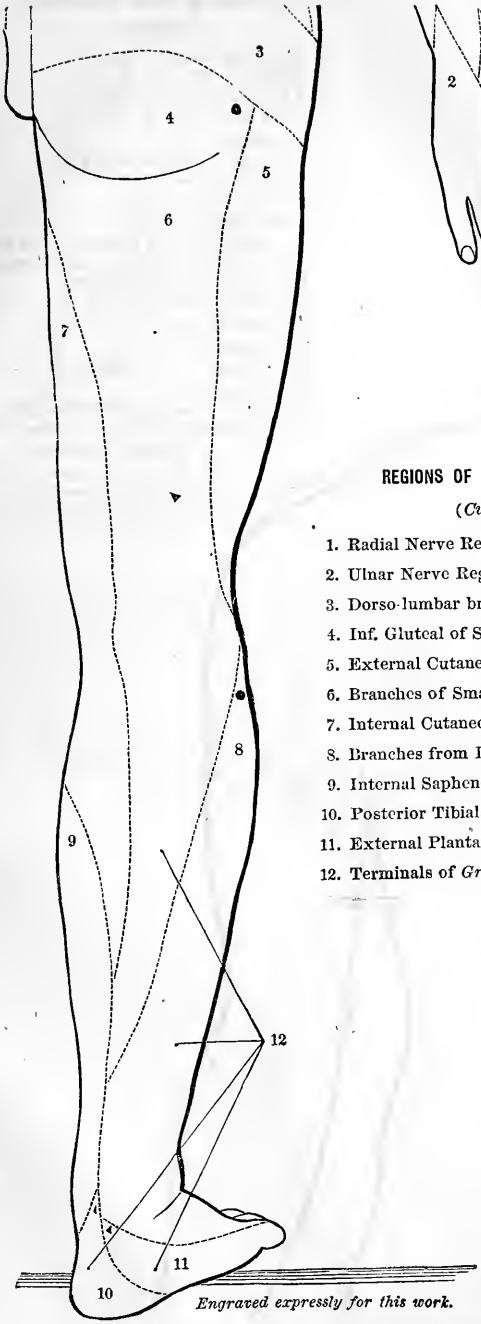

REGIONS OF NERVE TERMINALS.

(*Cutaneous.*)

1. Radial Nerve Region, B. P.
2. Ulnar Nerve Region, B. P.
3. Dorso-lumbar branches.
4. Inf. Gluteal of Small Sciatic, S. P.
5. External Cutaneous from Femoral, L. P.
6. Branches of Small Sciatic, S. P.
7. Internal Cutaneous, L. P.
8. Branches from External Popliteal, S. P.
9. Internal Saphenous, S. P.
10. Posterior Tibial, S P.
11. External Plantar, S. P.
12. Terminals of *Great Sciatic.*

Engraved expressly for this work.

Muscles of the Body, Anterior View. Fig. 128.

(See opposite page.)

1. Frontal Portion of the Occipito-Frontalis.
2. Orbicularis Palpebrarum.
3. Levator Labii Superioris Alæque Nasi.
4. Zygomaticus Minor.
5. Zygomaticus Major.
6. Masseter.
7. Orbicularis Oris.
8. Depressor Labii Inferioris.
9. Platysma-Myoides.
10. Deltoid.
11. Pectoralis Major.
12. Axillary Portion of the Latissimus Dorsi.
13. Serratus Major Anticus.
14. Biceps Flexor Cubiti.
15. Anterior Portion of the Triceps Extensor Cubiti.
16. Supinator Radii Longus.
17. Pronator Radii Teres.
18. Extensor Carpi Radialis Longior.
19. Extensor Ossis Metacarpi Pollicis.
20. Annular Ligament at Wrist and Instep.
21. Palmar Fascia.
22. Obliquus Externus Abdominis.
23. Linea Alba.
24. Tensor Vaginæ Femoris.
25. Section of the Spermatic Cord.
26. Psoas Magnus Muscle.
27. Adductor Longus.
28. Sartorius.
29. Rectus Femoris.
30. Vastus Externus.
31. Vastus Internus.
32. Tendon Patellæ.
33. Gastrocnemius.
34. Tibialis Anticus.
35. Tibia.
36. Tendon of the Extensor Communis.

Muscles of the Body, Posterior View. Fig. 129.

(See page 176.)

1. Temporalis
2. Occipital Portion of the Occipito-Frontalis.
3. Complexus.
4. Splenius.
5. Masseter.
6. Sterno-Cleido-Mastoideus.
7. Trapezius.
8. Deltoid.
9. Infra-Spinatus.
10. Triceps Extensor.
11. Teres Minor.
12. Teres Major.
13. Tendinous Portion of the Triceps.
14. Anterior Edge of the Triceps.
15. Supinator Radii Longus.
16. Pronator Radii Teres.
17. Extensor Communis Digitorum.
18. Extensor Ossis Metacarpi Pollicis.
19. Extensor Communis Digitorum Tendons.
20. Elecranon, and Insertion of the Triceps.
21. Extensor Carpi Ulnaris.
22. Auricularis.
23. Extensor Communis.
24. Latissimus Dorsi.
25. Its Tendinous Origin.
26. Posterior Part of the Obliquus Externus.
27. Gluteus Medius.
28. Gluteus Magnus.
29. Biceps Flexor Cruris.
30. Semi-Tendinosis.
31. } Gastrocnemius.
32. }
33. Tendo Achillis.

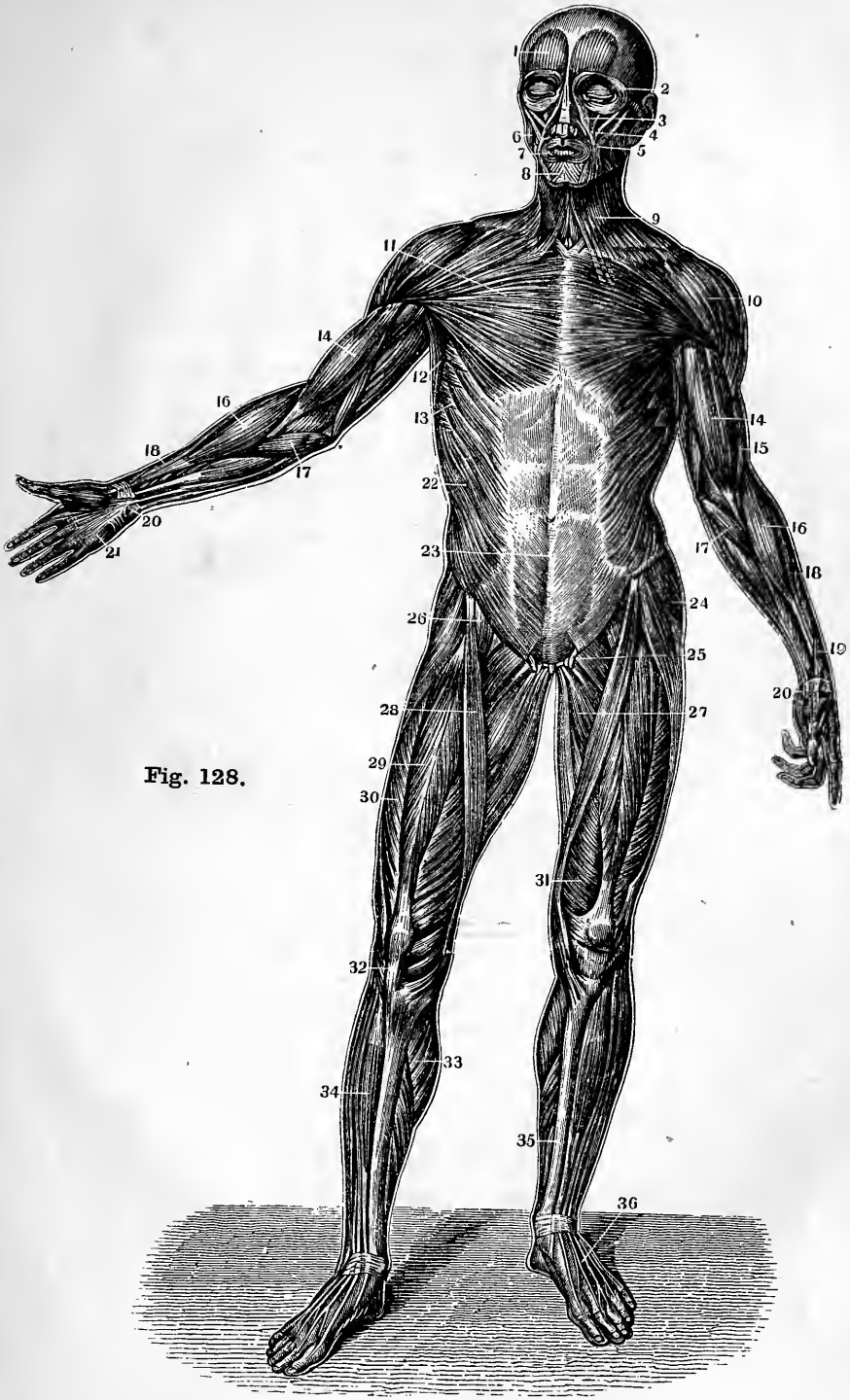
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Fig. 128.

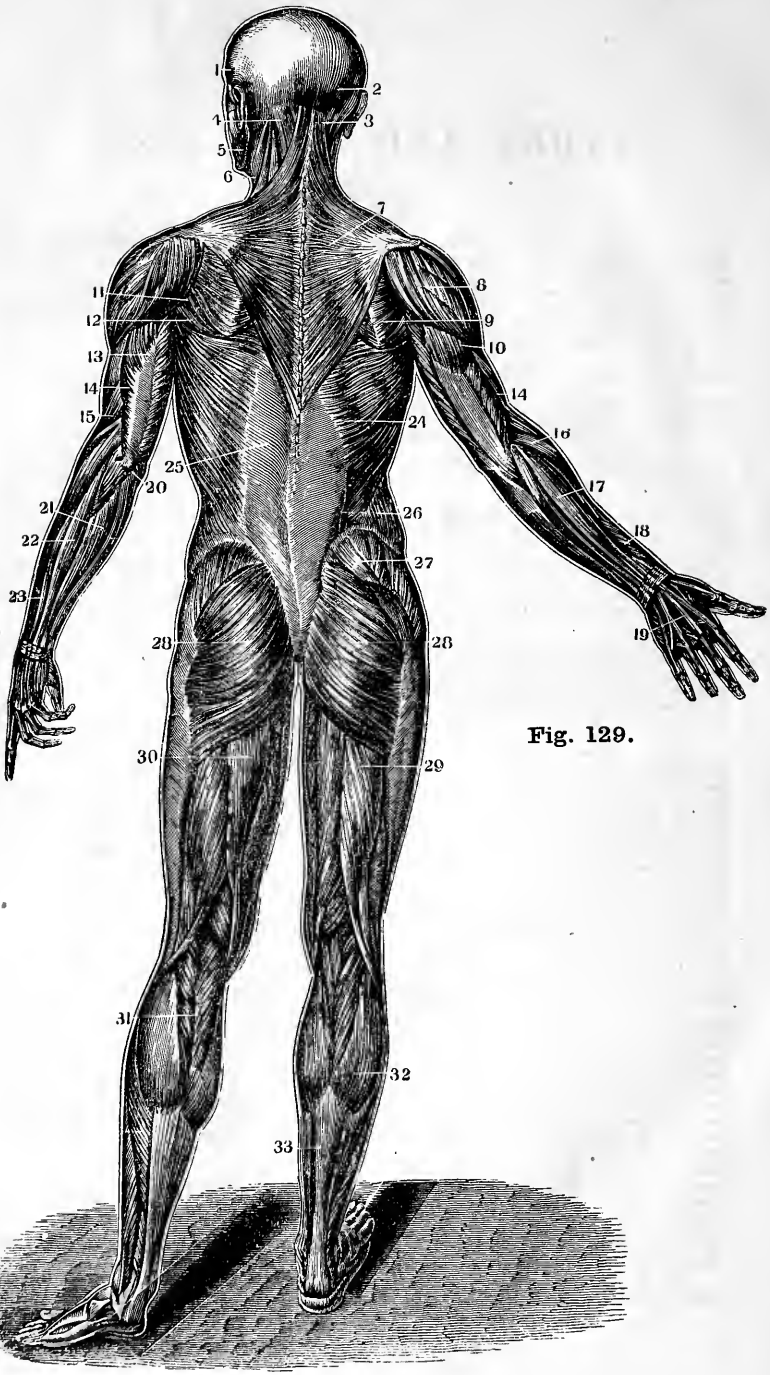
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Fig. 129.

INDEX AND INDICATOR.